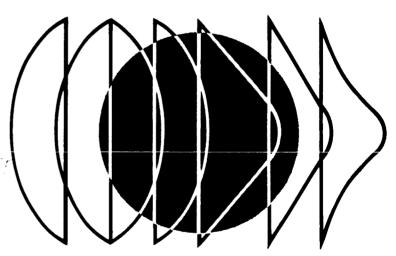PART C2 SUBSYSTEM FUNCTIONAL DESCRIPTION

VOYAGER CAPSULE PHASE B FINAL REPORT

VOLUME III SURFACE LABORATORY SYSTEM

COPY NO. 7

MCDONNELL ASTRONAUTICS

REPORT ORGANIZATION

VOYAGER PHASE B FINAL REPORT

The results of the Phase B Voyager Flight Capsule study are organized into several volumes. These are:

Volume I   Summary

Volume II   Capsule Bus System

Volume III   Surface Laboratory System

Volume IV   Entry Science Package

Volume V   System Interfaces

Volume VI   Implementation

This volume, Volume III, describes the McDonnell Douglas preferred design for the Surface Laboratory System. It is arranged in 5 parts, A through E, and bound in 8 separate documents, as noted below.

Part A   Preferred Design Concept   1 document

Part B   Alternatives, Analyses, Selection   3 documents, Parts B_1, B_2 and B_3

Part C   Subsystem Functional Descriptions   2 documents, Parts C_1 and C_2

Part D   Operational Support Equipment   1 document

Part E   Reliability   1 document

In order to assist the reader in finding specific material relating to the Surface Laboratory System, Figure 1 cross indexes broadly selected subject matter, at the system and subsystem level, through all volumes.

i

VOLUME III CROSS REFERENCE INDEX

VOLUME III PARTS / SYSTEM/SUBSYSTEM	PART A — PREFERRED DESIGN CONCEPT (Objectives, Constraints — System Description, Sequence of Operations, Subsystem Summaries.)	APPENDIX A (TO PART A) — ENVIRONMENTAL REQUIREMENTS	APPENDIX B (TO PART A) — FUTURE MISSION CONSIDERATIONS	PART B — ALTERNATIVES, ANALYSIS, AND SELECTION (Trade Studies, Supporting Analyses, and Results)	PART C — SLS FUNCTIONAL DESCRIPTIONS (Subsystem Descriptions)	PART D — OPERATIONAL SUPPORT EQUIPMENT (Equipment, Software and Trade Studies)	PART E — RELIABILITY (Constraints, Analysis, Results, Testing and Control)
Surface Laboratory System							
Mission — Objectives	Section 1	1.1 Environmental Design Criteria	1.1 Exploration Strategies	–	–	1. Introduction & Objectives	–
Mission — Constraints	Section 2	1.1 Environmental Design Criteria	1.1 Exploration Strategies	–	–	2. Requirements & Constraints	1 – Reliability Constraints 4 – Program Requirements
Mission — Profile	Section 3.1	1.5 Mission Environmental Conditions	1.2 Mission Profile	4.7 Extended Mission	–	–	–
Mission — Operations	4.1 Sequence 4.2 Timeline 4.3 Contingency Modes	1.3 Source of Environmental Parameters	–	2 – Mission Analysis	–	8. Software	2 – Failure Mode, Effects, Criticality Analysis 3 – Quantitative Estimates
Design — General	3.2 Configuration	1.2 General 1.4 Environmental Design Requirements	–	1 – Study Approach & Analysis 3 – System Functional Requirements 4 – Major Trade Studies	–	3. Preferred Approach 3.2 Design Concept 6 – ASHE & Servicing Equipment 7 – SC Mounted SLS Equipment 10. Analyses & Trade Studies	5 – Component Part Reliability
Design — Standardization/Growth	11 – Summary	–	–	–	–	4.3.8, 4.5.8	–
Design — Weight/Physical Characteristics	5 – Summary & Supporting Data	–	1.6 Constraints	–	–	4.3.3, 4.4.3, 4.5.3	–
Reliability	6 – Philosophy, Implementation, Definitions	–	–	4.6 Resource Allocation	–	4.3.6, 4.4.6, 4.5.6	–
Planetary Quarantine	7 – Contamination Analysis, Design for Sterility	1.6 Sterilization & Decontamination	–	–	–	–	–
OSE	8 – General Description	–	–	–	–	Complete OSE Description 3.3 Equipment Summary 4 – System Level Support Equipment 4.3 STC 4.4 LCE 4.5 MDE	–
Interfaces (Also See Volume V)	9 – System Interface Summary	–	–	–	–	4.3.5, 4.4.5, 4.5.5	–
Implementation (Also See Volume VI)	10 – Schedule & Program Summary	–	–	–	–	4.3.7, 4.4.7, 4.5.7	–
Major Subsystems	Section 3.3	–	–	4.3 Analysis of SL Alternatives 5 – Subsystem Studies	Complete Subsystem Functional Descriptions	5 – SL Subsystems Level Test Equipment 5.9 Automatic Processor 5.10 Miscellaneous 9. Equipment Summary	–
Electrical Power	3.3.1 – Requirements, Equipment Description & Operation	–	1.4 Major Considerations	5.1 Power Studies	Section 1	5.3 EPS Test Set	See Part C – Section 1
Sequencer	3.3.2 – Requirements & Description	–	–	4.4 In-Flight Monitoring & Checkout 5.2 Sequencing & Timing Studies	2.1 Sequencer & Timer 2.2 Test Programmer	5.4 Sequencer Subsystem Test Set	See Part C – Section 2
Control	3.3.3 – Requirements & Description	–	–	5.3 High Gain Antenna Pointing Studies	Section 3	–	See Part C – Section 3
Telecommunications	3.3.4 – Requirements & Description	–	–	5.4 Telecommunications Studies	4. Radio Subsystem 5. Antenna Subsystem 6. Command Subsystem 7. Telemetry Subsystem 8. Data Storage Subsystem	5.5 TCM Test Set	See Part C – Sections 4, 5, 6, 7, and 8
Structure (Including Mechanisms)	3.3.5 – Reqmts & Description 3.3.5.6 – Mechanisms	–	–	4.2 Leveling 5.5 Structural/Mechanical	9. Structure 10. Mechanical	–	See Part C – Sections 9, 10
Pyrotechnic	3.3.6 – Requirements & Description	–	–	Section 5.6	Section 11	5.8 Pyro Initiation Test Set	See Part C – Section 11
Packaging and Cabling	3.3.7 – Description	–	–	Section 5.7	Section 12	–	See Part C – Section 12
Thermal Control	3.3.8 – Description	–	1.5 Major Considerations	Section 5.8	Section 13	5.7 TCS Test Set	See Part C – Section 13
Science	3.3.9 – Sequence & Description 3.3.9.4 – Integration	–	1.3 Major Considerations 2 – Stationary Laboratories 3 – Extended Sample Gathering 4 – Mobile Laboratories 5 – Mobile Systems Performance	4.1 Science Integration 4.5 Independent Data Package Study 5.9.1 Science Data Subsystem 5.9.2 Sample Acquisition & Processing 5.9.3 Science Instruments	14.1 Science Data Subsystem 14.2 Sample Acquisition & Processing Equipment 14.3 Science Instruments	5.6 Science Test Set	See Part C – Section 14

Figure 1

ii-1   ii-2

TABLE OF CONTENTS

iv

SECTION 11

PYROTECHNIC SUBSYSTEM

11.1 EQUIPMENT IDENTIFICATION AND USAGE - The Pyrotechnic Subsystem contains (a) pin pullers which unlock the Surface Laboratory (SL) High Gain S-Band Antenna, Mars atmospheric sensors, subsystem probe, and surface sampler, (b) thrusters which deploy the four microorganism metabolism detectors, and (c) an actuator to deploy the subsurface probe. Electro-explosive device (EED) control modules, activated by the SL Sequencer & Timer (S&T) direct electrical power to redundant EED's which initiate the pyrotechnic energy release required to function the pin pullers, actuators and thrusters. A functional schematic diagram is shown in Figure 11-1.

11.1.1 <u>EED Control Module</u> - The EED control module contains the firing relays arming relays, firing capacitors and the safe/arm relays required to initiate the pyrotechnic functions as shown in Figure 11-2. A SL pyrotechnic firing circuit (#1), capable of initiating three EED's is shown in Figure 11-3. A completely redundant firing circuit (#2) is used to initiate the second EED installed in each pyrotechnic device. The OSE test connections that provide individual remote checkout of the safe/arm relay, arming relay, firing relay and EED are also shown.

After the firing circuitry has been checked-out the test connector is replaced with a shorting plug to maintain the circuit in a shorted condition in the event the arm relay is inadvertently actuated due to ground handling or other system testing. The shorting plug is replaced with a flight plug just prior to launch to guarantee separation of the contacts from the connector case and one another, and provide environmental protection during launch and transit to Mars.

11.1.2 <u>Electro-Explosive Devices (EED's)</u> - The EED's are hermetically sealed units threaded at one end to mate with a pyrotechnic device and terminated on the other end in an integral bayonet lock electrical connector shell surrounding two male pins. Each EED contains a single standardized bridgewire, an amount of ignition material and the varied output charge necessary to individually perform the functions shown in Figure 11-4. A minimum of two single bridgewire circuit EED's will be incorporated in each pyrotechnic device.

11.1.3 <u>Pyrotechnic Devices</u> - The pyrotechnic devices providing integrated support of SLS functions identified in Figure 11-4 are described below:

a.Pin Puller - The pin puller is a non-venting pyrotechnic gas operated device

FUNCTIONAL INTERRELATIONSHIP OF PYROTECHNIC SUBSYSTEM ELEMENTS
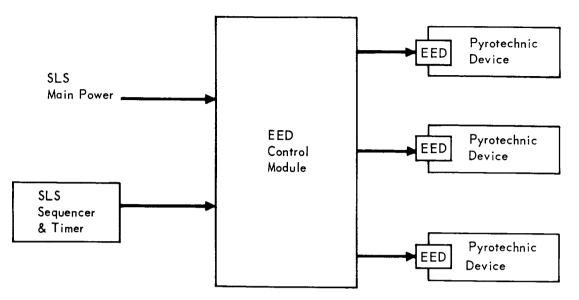
Figure 11-1

TYPICAL SLS PYROTECHNIC FUNCTIONAL COMPONENT SCHEMATIC

Figure 11-2

TYPICAL SLS PYROTECHNIC FIRING CIRCUIT
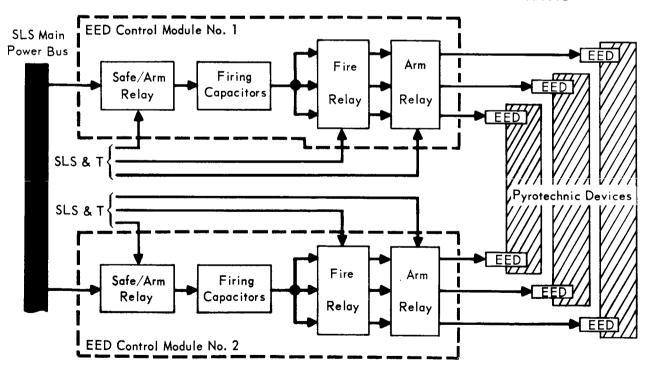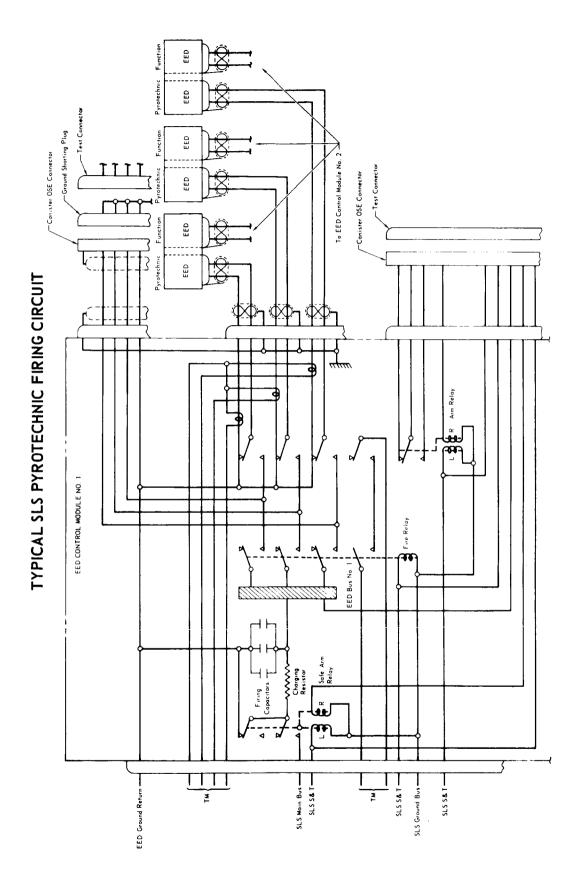
SLS INSTRUMENTS SUPPORTED BY PYROTECHNIC DEVICES

SLS INSTRUMENT	FUNCTION	PYROTECHNIC DEVICE SELECTED	PYROTECHNIC FUNCTION	NUMBER OF EED'S/DEVICE	TIME OF DEVICE FUNCTION
Antenna Pedestal	Release High Gain S-Band Antenna	Contained Pin Puller	Unlock Antenna Pedestal	2	T_{27}*
Atmospheric Probe	Release Mars Atmospheric Probe	Contained Pin Puller	Unlock Probe Arm	2	$T_{27} + 16_{min}$
Surface Probe	Release Surface Sampler	Contained Pin Puller	Unlock Sampler Arm	2	$T_{27} + 16_{min}$
Sub Surface Probe	Release Sub Surface Probe	Contained Pin Puller	Unlock Probe Arm	2	$T_{27} + 16_{min}$
	Deploy Sub Surface Probe	Contained Actuator	Rotate Probe Arm to Surface	2	$7_{27} + 17_{min}$
Microrganism Metabolism	Deploy 4 In Situ Modules	4 Contained Thrusters	Eject Modules	2	$T_{27} + 17_{min}(2)$ $T_{27} + 18_{min}(2)$

* T_{27} – Time of Mars Landing

Figure 11–4

11–4

that contains a piston which protrudes through the pin puller housing and is held in place with a shear pin. Upon initiation of either or both of the installed EED's the generated gases will be directed to the piston creating a force which breaks the shear pin and retracts the piston to a predetermined position.

b. Thruster - The thruster is a non-venting pyrotechnic gas operated device that contains a piston, generally retained at the bottom of tube, on top of which modules of equipment can be placed. Upon initiation of either or both of the installed EED's, the generated gases will be directed to the piston creating a force to un-lock the piston retention mechanism and rapidly propel the piston outward to a seal-ed stop. At this point the equipment module separates from the top of the piston, due to its kinetic energy and continues on a ballistic trajectory.

c. Actuator - The actuator is a non-venting pyrotechnic gas operated device that contains a retained telescoping piston to which equipment can be attached. Upon initiation of either or both of the installed EED's, the generated gases will be directed to the piston creating a force which unlocks the piston retention mechan-ism and forces the piston outward to a predetermined length.

11.2 DESIGN REQUIREMENTS AND CONSTRAINTS

11.2.1 Pyrotechnic Device - All pyrotechnic devices identified in Figure 11-4 will completely contain all the primary products of combustion and those secondary pro-ducts, such as separation debris, during and subsequent to their function. Contain-ment of these gases and debris further guarantees interference free operation of the Surface Laboratory science sensors. Careful material selection will be made to insure compatibility with the decontamination and dry heat sterilization cycles.

11.2.2 Electro-Explosive Devices (EED) - The standardized EED, used in all SL pyro-technic subsystem functions, conforms to the requirements and satisfies the con-straints stated in Section 4.2.12 of JPL Document No. PD-606-4, dated 12 June 1967. The pyrotechnic composition used in the EED's will be carefully selected for their ability to survive dry heat sterilization without detrimental degradation.

11.2.3 EED Control Module - The EED's will be shorted and grounded after install-ation until time for firing. No single failure or procedural error will cause the control module to inadvertently fire any EED's. The EED energy source will be isolated from other subsystem uses. A safe/arm device will remove power from the EED control module. All components in the control module will be compatible with ETO decontamination and will withstand the dry heat sterilization cycles. The con-trol module must contain the necessary provisions to telemeter the actuation of the

arm and fire relays for each pyrotechnic function and the firing of each EED. The control module must also contain the necessary provisions for remote checkout of the complete firing circuitry and EED bridgewire continuity after installation of the EED's.

11.3 PHYSICAL CHARACTERISTICS - Each EED control module is housed in a case measuring five inches wide by ten inches long by three inches high and will contain the components listed in Figure 11-5. Each EED control module will weigh approximately 4 pounds.

11.4 OPERATIONAL DESCRIPTION - Figure 11-2 is a functional schematic of the EED firing circuitry. Prior to landing the SL on the surface of Mars, the safe/arm relay prevents the EED firing capacitors from being charged. Immediately after landing the SL S&T provides a signal which actuates the safe/arm relay in each EED control module allowing these capacitors to charge within 30 seconds from the SL main bus. Upon receipt of separate arm and fire pulse from the SL S&T, the arm and fire relays will energize, discharging the capacitors through the selected EED's. A minimum of 30 seconds is required between pyrotechnic sequences to permit recharging of the firing capacitors.

11.5 PERFORMANCE OBJECTIVES - The standardized EED's used in the SLS Pyrotechnic Subsystem will provide the performance characteristics listed in Figure 11-6.

11.6 INTERFACE DEFINITION - The EED control module interface with the SL main power bus through electrical wire bundles to charge the EED firing capacitors; and with the SL S&T, through electrical wire bundles, which provides a preprogrammed command signal to initiate charging of the firing capacitors, latch the arm relays and activate the fire relays for all pyrotechnic sequences. The EED control modules interface with all the EED's installed in the pyrotechnic devices through wire bundles to provide the electrical power to sequentially initiate the EED's and subsequently function the pyrotechnic devices. Figure 11-4 shows the functions performed by the selected pyrotechnic devices. Pin puller pistons are inserted in the equipment to provide a positive interference lock before activation. Deployable equipment is attached to the thruster pistons which provide ballistic capabilities to the equipment. The actuator provides linear velocity to permanently attached components.

11.7 RELIABILITY AND SAFETY CONSIDERATIONS

11.7.1 Reliability Considerations - Each pyrotechnic function in the Surface Laboratory has been made highly reliable by the incorporation of redundant EED's

COMPONENTS CONTAINED IN EACH EED CONTROL MODULE

QUANTITY	COMPONENTS
2	5 amp – 6 Pole Latch Relay
2	5 amp – 4 Pole Latch Relay
3	5 amp – 4 Pole Nonlatch Relay
1	5 amp – 2 Pole Latch Relay
1	2 amp – 2 Pole Nonlatch Relay
3	Capacitor
9	Current Sensors

Figure 11–5

EED PERFORMANCE CHARACTERISTICS

● Pressure Seal Good to 20,000 psi After Firing

● Hermetic End Seal – Leakage Rate Not to Exceed 10^{-6} cc/sec (Helium) at One Atmosphere
    Differential Pressure

● Recommended Firing Current: 5 amps Over a Temperature Range of $-20°$ F to $+130°$ F

● Minimum All-Fire Current as Determined by Bruceton Test to be not Less Than 3.0 amps
    or .05 Joules

● Insulation Resistance Greater than 20 Megohms When 500 VDC is Applied Between
    Shorted Pins and Case

● Withstand Electrostatic Discharge of 25,000 volts Discharged Directly From 500 Picofarad
    Capacitor Between Pins and Case

● EED Body Material Essentially Nonmagnetic

Figure 11–6

11–7

in each device. Each of the two EED's is initiated by a completely independent firing circuit. Individual EED reliability is estimated to be no less than .9998 or less than one failure per five thousand firings. With redundant EED's device reliability is limited by the complexity of the function to be accomplished rather than EED reliability.

The functions to be performed in the Surface Laboratory are relatively simple. With redundant EED's, the reliability of each device is estimated to be no less than .99995, or one failure per 20,000 actuations. Since there are nine functions to be performed by the Surface Laboratory pyrotechnic subsystem, the subsystem reliability is estimated to be:

$$P_S \text{ (probability of mission success)} = .99955$$

Completely redundant electrical firing circuitry virtually eliminates the probability of failure due to absence of the proper electrical impulse, if sufficient electrical power is available at the source. For this reason, firing circuit effect on device reliability is considered negligible.

11.7.2 <u>Safety Considerations</u> - All EED's are considered Category A items as defined by AFETRM 127-1, dated 1 November 1966, due to the inaccessibility of the EED control modules and EED's after installation of the sterilization canister. The EED's are installed as separate items independent of their respective pyrotechnic device interface with other subsystems. The EED's are installed and mated with their firing circuit connectors, which are shorted by the arm relay, immediately before attaching the sterilization canister to minimize hazards to personnel during Capsule Bus final assembly.

11.8 TEST REQUIREMENTS - Development test, qualification tests, X-ray and neutron radiographic inspection previously performed on the assemblies, subassemblies and firing circuitry increase confidence of the subsystem preparedness for flight. Firing circuitry design permits pre-flight monitoring of the circuit components while maintaining the EED's in a shorted condition. The EED's can also be individually checked out after installation of the sterilization canister through the OSE provisions of the firing circuit while holding the remainder of the circuit in a safe condition.

11.9 DEVELOPMENT REQUIREMENTS - The selected Pyrotechnic Subsystem devices are either specifically designed to perform the intended functions, or existing hardware is modified to provide the desired functions. This design approach provides optimum mating subsystem performance rather than compromise this performance to

accommodate an existing "off the shelf" pyrotechnic device without modification.
The use of high temperature resistant propellants requires Phase C development
testing to determine the quantitative output energy as it applies to Surface Lab-
oratory Pyrotechnic Subsystem use.

McDonnell has determined by test that the Apollo Standard Initiator (ASI) will
survive the immediate effects of dry heat sterilization. A test is presently in
progress on the ASI to determine the effects of long term storage after dry heat
sterilization.

Extensive design analysis and development testing must be initiated during
Phase C if the use of dual bridgewire EED's capable of withstanding the 25,000 volt
electro-static discharge between the bridgewire is imposed as a requirement on the
SL Pyrotechnic Subsystem.

12.1 EQUIPMENT IDENTIFICATION - Packaging and cabling are the techniques of assembling components and subassemblies into assemblies to meet functional re-requirements, and interconnecting the assemblies to provide subsystem functions. Packaging covers the layout of internal component parts and their assembly, interconnection, and installation within an enclosure and the establishing of equipment geometry to meet both internal parts and exterior assembly mounting and intercon-nection requirements. Cabling covers the electrical interconnection of these assemblies within the Surface Laboratory and the provision of interfaces to OSE and the Capsule Bus.

12.2 DESIGN REQUIREMENTS AND CONSTRAINTS - Packaging and cabling design require-ments and constraints have been established for the design of the subsystems equipment and interconnections within the Surface Laboratory. These include use of circular connectors only for harness connections and establishment of a minimum wire gage as 24 AWG.

Proven fabrication processes for wire bundle fabrication assure assembly uniformity and provide inspection criteria. The processes selected for use on VOYAGER are listed in Figure 12-1.

12.3 PHYSICAL CHARACTERISTICS - The essential physical characteristics of the electronic equipment Packaging and Cabling Subsystem are indicated in Figure 12-2.

The standardized electronic subassemblies are installed in four racks, two on each side of the batteries. This arrangement permits flexibility of equipment location for mass and thermal balancing. The science equipment is positioned in the corners of the Surface Laboratory in proximity with their associated booms.

The cabling harness is attached to support panels and routed through the areas between the batteries and the equipment racks with crossovers between the batteries and the central decelerator enclosure. The main elements of the inter-connecting cabling are MIL-C-38999 connectors and MIL-W-81381/1 wire. The connectors are potted to provide environmental protection and additional wire support at the connector wire/contact transition. The individual wires are bundled into harnesses by the use of lacing tape. Wire bundle harnesses are established on the basis of signal class, physical routing and location of the harness installation within the vehicle. When a number of wires are routed together of the same classification (i.e., signals that will not cause interference

WIRE BUNDLE PROCESS SPECIFICATIONS

SPECIFICATION NO.	TITLE – DESCRIPTION
GENERAL WIRE BUNDLE PROCESSES	
PS 17400	Wiring, Electrical; Installation of
PS 17410	Wiring, Electrical, Spacecraft and Missile; Fabrication of
PS 17110	Wiring, Electrical; Identification of
PS 17111	Stripping of Electrical Wires
PS 17113	Lacing and Tying of Wiring
PS 17120	Bonding and Grounding; Electrical
PS 17153	Termination and Grounding of Shielding on Wire and Cable
PS 17172	Waterproofing of Electrical Connectors for Continuous Operation Temperatures up to 500°F
PS 17410.1	Assembly of Electrical Cable Terminals and Splices
PS 17410.2	Connectors, Electrical, Assembly of
PS 17410.3	Assembly of Radio Frequency Cable Assemblies
PS 17410.4	Connectors, Electrical, Crimp Type; Assembly of
PS 17420	Wiring, Electrical; Shielding of
PS 14070	Storage, Size Selection and Application of Heat Shrinkage Material
PS 20003	Inspection, Storage and Identification of Rubber Based Adhesives, Potting, and Sealing Materials
PS 22800	Soft Soldering of Electrical and Electronic Connectors
COMPACT WIRE BUNDLE PROCESSES	
PS 17115	Wiring, Electrical, Compact; Fabrication of
PS 17115.1	Wiring, Electrical, Compact; Twisting of Wires for
PS 17115.2	Application of Protective Jacket to Compact Electrical Wire Bundles
PS 17115.3	Wiring, Electrical, Compact; Application of Impregnating Compound
PS 17116.1	Coating of High Temperature Compact Electrical Wire Bundles
PS 17118	Wiring, Electrical, Shielded Compact; Fabrication of
PS 17118.1	Wiring, Electrical, Shielded Compact; Braiding of Shielding

Figure 12-1

12-2

SURFACE LABORATORY EQUIPMENT INSTALLATION

Standardized Subassemblies
Main Trunk Wire Routing

Science
EED Control Models
Science
Battery
Science
Battery
Science
Battery
Digital Signals
Analog Signals
Power and Control
SL/CB Interface
Science
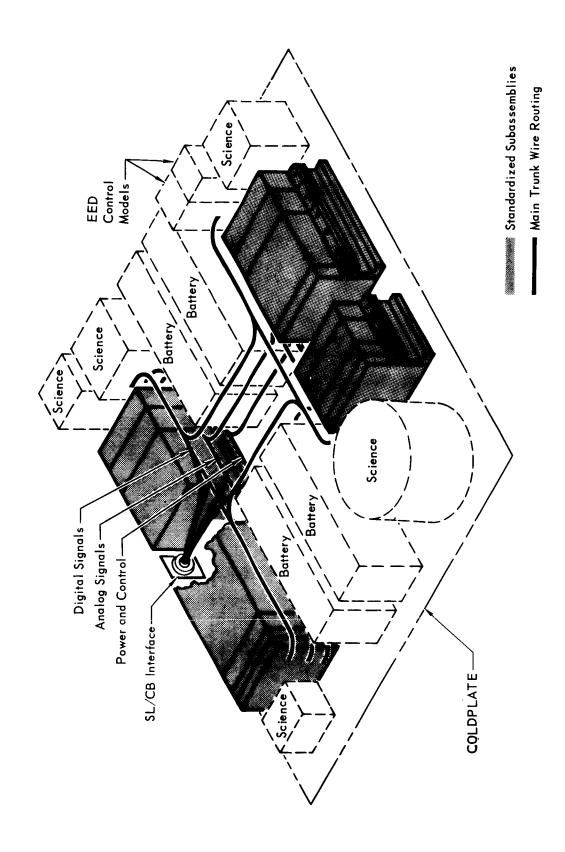Battery
Battery
Science
Battery
Science
COLDPLATE

Figure 12-2

12-3

to each other but may cause electromagnetic interference to or be susceptible to other classes of signals), they are bundled together and covered with a common shield jacket. These cables are then routed as a separate cable or combined with other wires of the same signal class and bunded into a harness.

Sleeving is applied to the harnesses at local areas of possible abrasion or handling damage. Where wiring is routed through structure or support panels, grommeted holes are provided. The support panels provide support area sufficient to allow separation of wire bundles according to signal type and permit routing of a trunk harness for interconnection of equipment, OSE, and the interface to the Capsule Bus. The trunk wiring contains direct interfacing connectors to equipment, except in cases where multiple interconnections between specific equipments warrant the addition of an intermediate disconnect between the trunk wire bundle and these equipments. The use of direct connections from the trunk reduces the interconnecting cabling weight, volume and interfaces; therefore increasing the reliability.

12.4 OPERATION DESCRIPTION - All equipment interconnects within the Surface Laboratory are made using MIL-C-38999 connectors. Manually mated miniature circular plugs are easily aligned and allow visual inspection of positive locking. During fabrication of interconnecting cables, all plugs are aligned and keyed on three-dimensional wire harness boards so that coupling to the mating equipment in the Surface Laboratory will require minimum rotation of the plug, prior to mating. Final coupling and locking is completed by one quarter turn of the plug coupling ring.

12.5 RELIABILITY AND SAFETY CONSIDERATIONS - Reliability of the Surface Laboratory interconnecting cabling is assured by study of the requirements and constraints of each wire, connector and contact of each subsystem. Each step in the design of interconnecting circuits considers peak signal level voltage and current requirements, electromagnetic interference, mechanical strength, fabrication techniques, and routing and installation within the Surface Laboratory.

Pyrotechnic initiator firing circuits are designed to provide complete check-out and safety of pyrotechnic devices after installation into the sterilization canister. All initiation devices and circuits are considered Category A devices as defined by Air Force Eastern Test Range Manual AFETRM-127-1, dated 1 November 1966. Potential safety hazards due to high voltages associated with the

12-4

radio frequency equipment are minimized by standard RF handling precautions.

12.6 TEST REQUIREMENTS - Tests specifically conducted on wiring and packaging are not required during flight. Subsystem tests with signal and power transfer will indirectly test the cabling.

12.7 DEVELOPMENT REQUIREMENTS - Components and materials required to implement high reliability equipment packaging and cabling systems have been selected from MAC Report E936 "VOYAGER Candidate Materials." These components and/or materials are developed into subassemblies and assemblies by progressive testing at each assembly level. Where components and materials not listed in the report are required, special testing will be established to determine their compatibility with ethylene oxide (ETO) and heat sterilization.

Testing of a connector type, wire types and potting compounds has been initiated to determine the effect of ETO and heat sterilization and 200 days vacuum storage. Two identical assemblies have been fabricated, one to be subjected to the test environments and one for control. The latter will be stored at room temperature. In addition to the potting compatibility test results to be derived from the connector assembly testing, a potting slug containing only wires is also being tested to evaluate a third compound. The test articles are configured as shown in Figure 12-3.

One particular aspect of electronic packaging is expected to warrant considerable development effort with both basic materials and equipment design. This is the voltage breakdown problem.

Since the Mars atmosphere is predicted to fall within the critical breakdown region and the VOYAGER equipment must undergo long term space vacuum exposure, the problem will be given particular attention. There appears little chance to use previous expedients such as the hard vacuum of space or fluid (liquid and gas) filled devices to circumvent the problem. It is concluded that the best approach is to attack the problem using insulating, encapsulating and embedding materials which have been thoroughly cured and outgassed. Good adhesion is also a prime requisite. Studies to date show that the standard urethane foams are not satisfactory, although newer products (over conformally coated materials) may have potential. It now appears that the epoxy or silicone materials, in both the unfilled and syntactic forms, offer the most promise.

The Surface Laboratory subsystems will be expected to perform for a long period of time in the critical pressure breakdown regime. The design details noted as warranting special attention for Capsule Bus equipment require additional

12-5

WIRE ASSEMBLY TEST CONFIGURATION –
ETO, HEAT STERILIZATION AND VACUUM STORAGE

22 GA Wire Per
MIL–W–16878 Type E

22 GA Wire Per
MIL–W–81381/1

Bendix JT06RP–12–98S(011) Plug
Potting – 3M Company EC 1663
Sealing Compound and EC 1694
Primer

Bendix JT00RP–12–98P(011) Recpt
Potting – MIL–S–23586, Type II,
Class II

Individual Connector Contacts on Each
Wire Covered With Shrink Tubing

Potting Slug
3M Company EC 1663
Sealing Compound
and EC 1906 Primer
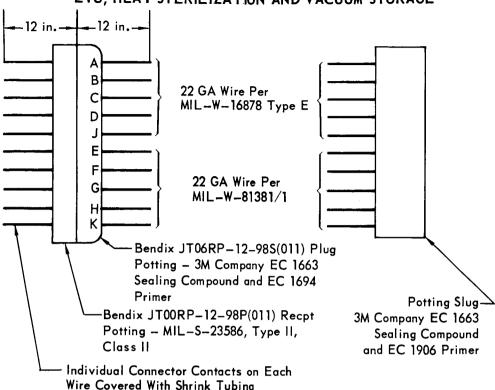
Figure 12–3

emphasis for the Surface Laboratory. Whereas the goal of suppressing corona
to a non-arcing level so as not to interfere with other equipment is sufficient
for some designs, it is inadequate for the Surface Laboratory equipment. Not
only will this equipment be required to preclude the omission of breakdown induced
electromagnetic noise, but it will also be necessary to assure that long term
corona does not progressively degrade dielectrics.

SECTION 13

THERMAL CONTROL SUBSYSTEM

The Thermal Control Subsystem maintains Surface Laboratory (SL) temperatures within their allowable ranges throughout all mission phases. Temperature control is provided to temperature sensitive science instruments and batteries in the Electrical Power Subsystem. Prior to landing, the subsystem operates within the overall temperature environment provided by the Capsule Bus Thermal Control Subsystem. After landing it operates independently, within the Mars surface environment.

13.1 EQUIPMENT IDENTIFICATION AND USAGE - The preferred SL Thermal Control Subsystem consists of heat pipes, electrical heaters with thermostats, insulation, thermoelectric devices, phase change materials, and surface coatings. The heat pipe components include an internal heat distribution plate, external radiators, and interconnecting plumbing. A temperature actuated valve, which serves as a control device, is installed between the radiator and the heat distribution plate. The internal equipment is mounted on the heat distribution plate. The excessive heat generated by the equipment during the daytime operation is absorbed by this plate which then transfers the heat via the heat pipes to the externally mounted radiators where the heat is transferred to the environment. The function of the insulation is to minimize the heater power required for thermal control during the continuous cold condition with Mars cloud cover.

Certain individual equipment and experiments located both internal and external to the primary equipment package are provided with thermoelectric devices and/or phase change materials and insulation to provide for maintenance of small temperature tolerances. The thermoelectric devices either absorb or generate heat as required. The phase change materials function as heat sinks to absorb excess heat.

13.2 DESIGN REQUIREMENTS AND CONSTRAINTS - The major requirement is to design a SL Thermal Control Subsystem with the dual capability of heat dissipation and retention to accommodate the extremes of the Mars environment and equipment power.

13.2.1 <u>Equipment Temperatures</u> - The temperature requirements of all subsystems and most of the experiments are within the selected SL operating temperature range of 50°F to 125°F. This range is applicable to equipment inside the SL. It corresponds to that allowable for the batteries, which contribute most of the

MCDONNELL ASTRONAUTICS

internal SL weight. Other equipment located both inside and outside the SL have temperature requirements which are not within this range. These items are individually temperature controlled using appropriate combinations of insulation, heaters, thermoelectric devices and/or phase change materials.

13.2.2 Equipment Power Levels - Thermal energy from equipment operation must be accommodated throughout the mission. The design conditions for thermal control occur after landing. These are: peak load during daytime transmission periods, 312 watts; and minimum load during night operations, 100 watts.

13.2.3 Environment - The post landing environmental conditions are most critical for SL thermal control design. These are:

   a. Continuous cold environment with a -190°F ambient temperature.

   b. Cyclic environment with day and night ambient temperature extremes of 120°F and -80°F respectively.

   c. Terrain slopes of $\pm$ 34°.

   d. Sand and dust environment which can degrade thermal control coatings.

   e. Winds which affect SL heating or cooling.

Additional details on the Mars surface environment plus those of the flight phases are presented in Part B, Section 5.8.

13.3 PHYSICAL CHARACTERISTICS - The selected SL Thermal Control Subsystem is shown schematically in Figure 13-1. Basic physical characteristics of the subsystem are listed below.

Exterior Surface Coatings: Flame sprayed aluminum oxide -- preliminary choice

Size: Two opposed vertical radiators, each 7.75 ft^2 area, total 15.5 ft^2

         4.0 inch thick insulation, glass fiber with silicone binder -- preliminary choice.

Weight: 3.0 lb Electrical heaters and thermostats

           2.0 lb Thermal control coating

          31.0 lb Heat pipe assemblies

          95.0 lb Insulation

         131.0 lb Total   (This does not include 97 lbs of batteries required to supply heater power).

13.4 OPERATION DESCRIPTION - A schematic depicting the operation of the SL primary equipment package Thermal Control Subsystem is shown in Figure 13-1. The SL Thermal Control Subsystem attenuates the effects of external environment fluctuations to avoid either overheating or cooling of the equipment. After the initial launch transient, the Capsule Bus temperatures stabilize during interplanetary cruise to a

SL PRIMARY EQUIPMENT PACKAGE THERMAL CONTROL SYSTEM OPERATION

HEAT INPUTS

Equipment Heat Radiated

Direct Solar & Reflected Solar Radiation

Convection In or Out

Mars Surface Radiation

~ – Heat Pipe Fluid Circuit

Q_H – Electrical Heater

HT – Heater Thermostat, Open for $T_E < 50°F$

Q_E – Equipment Heat Dissipated

T_R – Radiator Temperature

T_E – Equipment Temperature

Insulation

Radiator

Electrical Heater

Heater

Battery

Q_H

HT

Equipment

$\sim Q_E$

Equipment Heat Distribution Plate

Heat Pipe Control Valve
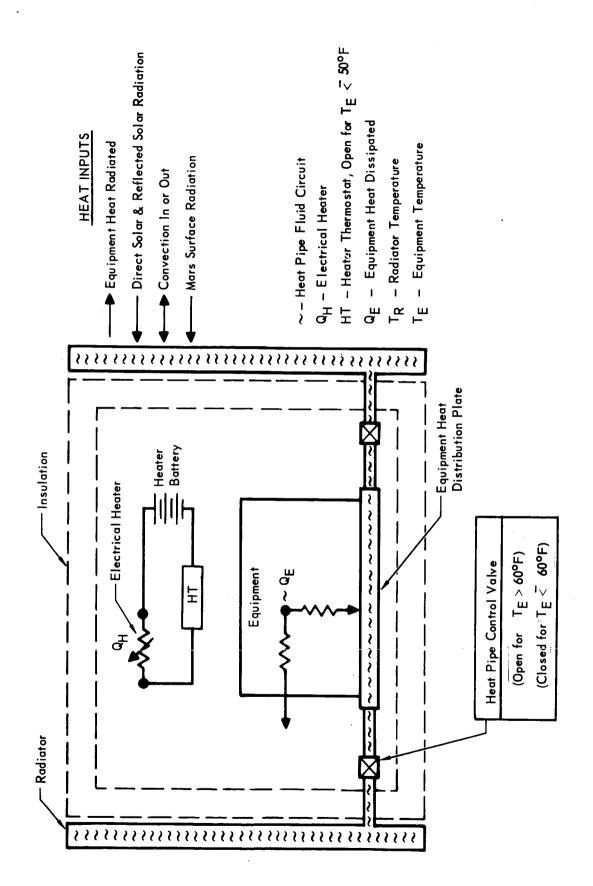
(Open for $T_E > 60°F$)

(Closed for $T_E < 60°F$)

Figure 13–1

low value (near -140°F) except in other thermally controlled areas. The SL temperatures, without thermal control, would reach this same minimum value. The combination of electrical heaters and insulation prevents this cooldown in the SL, and maintains equipment temperatures within their survival ranges.

During periods when Spacecraft power is interrupted, e.g., trajectory corrections, the insulation also serves to reduce the cooldown rate. This rate, less than 2°F/hour in the preferred design will avoid obtaining excessively low equipment temperatures before the power supply is restored (1.5 to 3 hours without power is possible). During Mars atmospheric entry the insulation and coatings again serve to attenuate heat input from the interior of the Aeroshell.

After landing the same thermal control equipment continues to function. In addition, the heat pipes serve to reject equipment generated heat in the following manner. During daytime operations the equipment generated heat warms the SL until a temperature of 60°F is attained. At this temperature the heat pipe control valve opens, the heat pipe fluid vaporizes in the equipment heat distribution plate and is allowed to move to the radiators. The fluid condenses in the radiators, releasing the equipment heat which is absorbed, then returns to the heat distribution plate to repeat the cycle. The heat pipe operation is continuous until the equipment temperature falls below 60°F, which will cause the control valve to close. The two opposed radiators operate independently of each other with separate control valves. The radiators are designed such that one radiator alone can dissipate the equipment heat load when the other is in direct sunlight. At night when the equipment temperature decreases to 50°F, the heater thermostat turns on the electrical heaters and maintains the equipment at 50°F.

13.5 PERFORMANCE CHARACTERISTICS - Figure 13-2 lists the principal performance characteristics of the SL Thermal Control Subsystem. The characteristics of equipment temperature and heater power requirements are shown for the nominal 27 hour morning terminator landing mission, a diurnal cycle nominal mission extension, and an evening terminator landing mission.

13.6 INTERFACE DEFINITION - The following list defines the interfaces that exist between the SL and the CB.

   a. Minimization of heat transfer paths across field joints.

   b. The view to space of the SL radiators must not be obstructed.

   c. Electrical power required for the SL heaters.

   d. Heating from rocket motors on SL base region during entry.

   e. Temperature monitoring throughout mission.

SL THERMAL CONTROL SUBSYSTEM
PERFORMANCE CHARACTERISTICS

CHARACTERISTICS	MISSION		
	NOMINAL – 27 HR MORNING LANDING	EXTENDED NOMINAL MISSION – 1ST DAY & NIGHT	EVENING TERMINATOR LANDING
Equipment Temperature – °F			
● Maximum – Day	100	77	115
● Minimum – Night	50	50	50
*Nighttime Peak Heater Power–Watts			
● Cyclic Environment	83	100	≃ 83
● Cloudy Environment	210	** –	210
*Nighttime Integrated Heater Power – Watt-hrs.			
● Cyclic Environment	740	1000	≃ 740
● Cloudy Environment	4000 (19 hrs)	** –	6300 (30 hrs)
* – 116 Watts of Equipment Dissipated Heat Not Included.			
** – Mission extension applicable only to cyclic nominal mission.			

Figure 13–2

13–5

f. Capsule Bus thermal control provides SL environment prior to landing.

Interfaces of the SL Thermal Control Subsystem to other SL subsystems are as follows:

a. Electrical supply for heaters after landing.

b. Experiment temperature requirements.

c. Telecommunication for temperature monitoring.

d. Experiment and equipment mountings must have good heat transfer characteristics.

13.7 RELIABILITY CONSIDERATIONS - The reliability considerations concerning the Thermal Control Subsystem were simplified by the passive nature of the subsystem; i.e., resistance heaters, thermostats, thermoelectrics, heat pipes and insulation. No dynamic components are involved. All elements of the subsystem involve present day hardware and techniques.

13.7.1 Operational Reliability - The subsystem is configured simply, however, considerable attention has been directed to operational reliability provisions as follows:

a. The resistance heaters and associated control thermostats are considered as being non-essential during the cruise phase. This is due to the fact that battery charging will generate sufficient heat to satisfy the cruise phase requirements.

b. Spacecraft command capability exists as to availability of heater bus power. This is in addition to thermostat control.

c. Heat pipes have demonstrated, under limited McDonnell testing, capability to handle loads far beyond rated capacity. This capability provides for mission success should some loss of heat pipe efficiency occur. Thus, thermal control probability is enhanced over the complementary mean noted.

13.7.2 Failure Mode, Effect and Criticality Analysis (FMECA) - A failure mode, effect and criticality analysis was conducted for the Thermal Control Subsystem and the results are presented in Figure 13-3. Each failure mode is categorized according to the effect on the following mission objectives:

a. Achievement of Flight Capsule landing.

b. Performance of Entry Science experiments.

c. Performance of Landed Science experiments.

d. Retrieval of engineering data.

The failure categories are defined as follows:

FAILURE MODE, EFFECT AND CRITICALITY ANALYSIS
SL THERMAL CONTROL SUBSYSTEM

COMPONENT OR FUNCTION	FAILURE MODE	FAILURE EFFECT	FAILURE CATEGORY				REMARKS
			LANDING	ENTRY SCIENCE	LANDED SCIENCE	ENG. DATA	
Resistance Heaters & Thermostats							
Proximity (10)	Open	a) Cruise – None	1	1		1	Resistance heaters considered redundant to battery heat.
		b) Landed – Degradation	1	1	2	1	Without resistance heaters, the SL volumetric region may reach degrading temperatures.
Experiments	Open	Landed Only – Degradation	1	1	2	1	Without resistance heaters, the equipment may reach degrading temperatures.
Heat Pipe							
Radiators (2)	Leakage	Heat Pipe Degradation	1	1	2	1	Equipment on that heat pipe could potentially reach excessive temperatures due to heat pipe efficiency loss.
Heat Pipes (4)	Wicking	Heat Pipe Degradation	1	1	2	1	Same as radiator leakage.
Control Valves (4)	a) Stick Open Seal Leakage	Degradation	1	1	2	1	Shorten mission due to excess night power demand for heaters
	b) Stick Closed	Degradation	1	1	2	1	Curtail or shorten mission cycle equipment in operational hours or cycles to prevent excess operation.

CATEGORY DEFINITIONS

1 – No effect on mission objective.
2 – Degrading effect on mission objective.
3 – Possible catastrophic effect on mission objectives.

Note: Closed failure mode for heaters and thermostats not applicable due to backup command shut off capability.

Figure 13–3

13–7

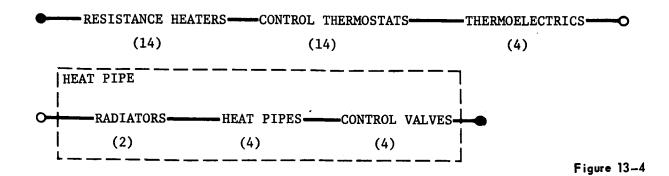| Category	Effect
1	no effect on mission objectives
2	degrading effect on mission objectives
3	possible catastrophic effect on mission objectives

In keeping with the statements made above as to enhancement of mission success capability, the Thermal Control Subsystem FMECA analysis evidences no category three failures and only possible category two failures. There are three potential heat pipe failure modes:

1. Loss of working fluid, either from a slow leak or structural failure.

2. Failure of the control valve in the closed position.

3. Failure of the control valve in the open position.

The result of the first two failure modes is the same, a reduction in the daytime heat rejection capabilities. (The vapor chambers for each of the four heat pipes in the system are not interconnected. Thus, a leak in a single vapor chamber will fail only one heat pipe). Loss of a single heat pipe would be of little consequence. The peak daytime temperature would increase only 5°F, from 100°F to 105°F. Even the loss of all four heat pipes would not completely compromise the mission since the Thermal Control Subsystem would essentially revert to the passive subsystem described in Section 5.8 of Part B. This subsystem can survive the first communication period, and overheats only during the second communication period. A much more severe heat pipe valve failure mode occurs when a valve fails open, where for the cold environment condition the heat loss through the heat pipe would be sufficient to drain the SL batteries, due to excessive heater demands. However, even though this condition is most unlikely to occur, it can be easily remedied by including one or more pyrotechnic valves which would be fired to vent the heat pipe working fluid, thus effectively causing the subsystem to revert to the much less severe closed valve failure mode. Since the probability of heat pipe valve failure is so remote, pyrotechnic valves are not included in the SL Thermal Control Subsystem. In any event data will be obtained for one full day-time period for the nominal morning landing mission.

13.7.3 Reliability Estimate - The functional logic relationship of components in the Thermal Control Subsystem are depicted in the Reliability Diagram, Figure 13-4. The Reliability Estimate Summary, Figure 13-5 evidences the Thermal Control Subsystem calculated reliability of .9939.

13-8

SL THERMAL CONTROL
RELIABILITY DIAGRAM

● ──RESISTANCE HEATERS───CONTROL THERMOSTATS────────THERMOELECTRICS──○
　　　　　(14)　　　　　　　　　　(14)　　　　　　　　　　(4)

┌─ ─┐
│ HEAT PIPE　　　　　　　　　　　　　　　　　　　　　│
│　　　　　　　　　　　　　　　　　　　　　　　　　　　│
○─┼──RADIATORS────────HEAT PIPES───────CONTROL VALVES─┼─●
│　　　(2)　　　　　　　(4)　　　　　　　(4)　　　　　│
└─ ─┘

Figure 13-4

SL THERMAL CONTROL
RELIABILITY ESTIMATE SUMMARY

COMPONENTS	tm (1)	∂ (2)	$-LnRx10^6$ (3)
Cruise			
Proximity Resistance Heaters (10)	5549	–	≈ 0
Control Thermostats (10)	5549	–	≈ 0
Redundant to Battery Heat			
Landed			
Proximity Resistance Heaters (14)	87	0.10	9
Control Thermostats (14)	87	0.20	17
Thermoelectrics (4)	87	0.12	10
Heat Pipe			
Radiators (2)	87	10.00	870
Heat Pipes (4)	87	40.00	3480
Control Valves (4)	87	19.4	1688
			6084 4R = .9939

Notes: (1)　tm = modified time factor x time (hours)
　　　　 (2)　 ∂ = failures per million hours
　　　　 (3)　 $-LnR \times 10^6$ = tm∂

Figure 13-5

13-9

SCIENCE SUBSYSTEM

The functions of the Science Subsystem which includes the Science Data Subsystem, the Sample Acquisition and Processing Equipment and the Science Instruments are summarized in Figure 14-1. Functional descriptions of the equipment required for carrying out the scientific mission appear in sections 14.1 through 14.3.

SCIENCE SUBSYSTEM FUNCTIONS

EQUIPMENT	FUNCTIONS
Science Subsystem	Automatic device to 1. Photograph the area around the Lander 2. Make spectral solar radiation and climatological measurements 3. Collect atmospheric, subsurface gas and soil samples. 4. Make a biological and chemical analysis of the samples 5. Process the data and transfer it to the telemetry subsystem
Science Data Subsystem	1. Sequencing and control of the science instruments and the sample acquisition and processing equipment* 2. Calibration, range switching data acquisition, and data storage
Science Acquisition and Processing Equipment	1. Collect surface and subsurface atmospheric and soil samples. 2. Make a measurement of the bulk density of the soil sample 3. Meter samples according to volume requirements to the instruments for analysis
SCIENCE INSTRUMENTS	
Camera	1. Photograph in stereo a panoramic view 360° x 90° plus five 24° x 24° frames
Atmospheric Measurements Package	Measurements over at least one diurnal cycle of 1. Pressure $\pm$ 1 percent 2. Temperature $\pm$ 1 percent 3. Humidity 4. Wind speed accurate to $\pm$ 5° and direction accurate to within 15°
Spectro-Radiometer	1. Spectral measurements of the near surface, far surface, sky and sun with 35 wavelength bands between 0.2 and 30 microns with a $\pm$ 15° field of view 2. Total solar radiation measurement within a $\pm$ 60° field of view
Alpha Spectrometer	Measurement of the alpha backscatter and proton spectrums resulting from the bombardment of prepared soil samples by alpha particles from a radioactive source
Gas Chromatograph	Measurement of the chromatograph spectrums using four columns for atmospheric, subsurface atmospheric and soil volatile samples including the pyrolysis to produce the soil volatiles
Specific Life Detectors	Detection of growth, metabolism, and photosynthesis using simple cultures and both prepared samples and in situ measurements
Subsurface Probe Sensors	Measure subsurface temperature using nine temperature sensors on the subsurface probe

*Part of the control function by TM subsystem

Figure 14-1

14-1

14.1 SCIENCE DATA SUBSYSTEM - The Science Data Subsystem (SDS) in the Surface Laboratory (SL) has two functions. The first function is to acquire and format data from the science instruments into a coherent bit stream and transfer this data to the SL Telemetry (TM) Equipment for subsequent transmission to Earth by the Radio Subsystem. The second function is, upon receipt of a start signal from the SL TM, to provide commands necessary to sequence each science instrument through its experiment program.

14.1.1 Equipment Identification and Usage - The SDS has the following major components:

    a. Visual Imaging Remote Interface Unit

    b. Atmospheric Properties Remote Interface Unit

    c. Soil Analysis (Alpha Spectrometer) Remote Interface Unit

    d. Gas Analysis (Gas Chromatograph) Remote Interface Unit

    e. Life Detection (Metabolism 1 and 2) Remote Interface Unit

    f. Life Detection (Growth) Remote Interface Unit

    g. Subsurface Probe Remote Interface Unit

    h. Spectroradiometer Remote Interface Unit

    i. Soil Sampler and Processor Remote Interface Unit

    j. DC to DC Converter

Figure 14.1-1 is a functional block diagram of the SL SDS. Figure 14.1-2 illustrates a typical science time line for the 1973 mission.

The data requirements of the SL SDS are defined in Figure 5.4-4 of Part B, Volume III, "The Surface Laboratory Instrumentation List." The equipment works principally in conjunction with the following:

    a. The SL TM which provides on-off and mode selection control for each Remote Interface Unit (RIU) and temporary storage for science data, and

    b. The science instruments.

The SL SDS has a total of 116 data inputs; 41 of which are single ended high level, 44 are double ended low level, 18 are bilevel and 13 are digital. The SDS provides a total of 57 sequencing commands to the science instruments and receives 15 status commands from these instruments. Only those signals which are active during a given experiment are monitored and transferred to the SL TM for telemetering.

14.1.2 Design Requirements and Constraints - Aside from the usual VOYAGER requirements and constraints of;

SCIENCE DATA SUBSYSTEM
FUNCTIONAL BLOCK DIAGRAM

HL Analog

LL Analog

Bi-level

Digital

Remote Interface Unit No. 1

No. 2

No. 3

No. 4

No. 5

No. 6

No. 7

No. 8

No. 9

Experiment Inputs Including:
Visual Imaging
Atmospheric Properties
Alpha Spectrometer
Gas Chromatograph
Metabolism 1 & 2
Life Detection (Growth)
Subsurface Probe
Spectroradiometer
Soil Sampler & Processor

Control from
SL TM

High Level
Analog
Inputs

Mplx High
Level
Analog
Signals

P

C

Low Level
Analog
Inputs

Mplx Low
Level
Analog
Signals

P   C

Bi-level
and Digital
Inputs

To All RIU's

On/Off
and Mode
Selection
Control
Inputs from
the Surface
Laboratory
Telemetry
Equipment

Mode Contro

Control

DC–DC
Conversion

Figure 14.1–1

14.1–2 –(

REMOTE INTERFACING UNIT NO. n (TYPICAL)

Data
to
SL TM

1
2
3

n

Amplifier

2nd/3rd
Level
Multiplex

Sample
and
Hold

A/D
Conversion

Digital
Multiplex

P   C   P   P   C

P   P   P

Program
Logic

State
Storage

Power to
RIU Functions

Division
and
Accumulation

C
C

14.1-2-2

SCIENCE SEQUENCE
MORNING LANDING

A. SOLAR PHASE EVENT TIMES – SEQUENCE FOR 1973 MISSION CONSTRAINTS
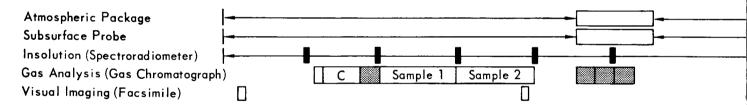
B. SCIENCE SEQUENCE COMPARED WITH EVENT SEQUENCE FOR PREFERRED MORNING LANDING SITE (0° Lat

1. Solar Event Referenced Science Sequence

Atmospheric Package
Subsurface Probe
Insolution (Spectroradiometer)
Gas Analysis (Gas Chromatograph)
Visual Imaging (Facsimile)

2. Touchdown Referenced Science Sequence

Soil Analysis (α Spectrometer)
Metabolism (In Situ Portion)
Metabolism I & II
Growth
Sample Processing
Surface Sampling
Deployment
Engineering Sequence

Figure 14.1–2

14.1-3 – 1

τ = Central Angle to Terminator
N = Noon
ES = Earth Set (34° Slope)
SS = Sun Set (0° Slope)
ER = Earth Rise (34° Slope)
SR = Sun Rise (0° Slope)

5 April 1974
5 January 1974

Date Limits
Launch Opportunity

N   ES

ER   SR

14   15   16   17   18   19   20   21   22   23   24   25   26   27   28   29   30   31   32

Time – Hours

ite, Time Reference T = 0 When τ = 15°

tude, τ = 25°, 24 March 1974)

M   ER–SR   N   ES

Sample 3   Sample 4   C   C

Commanded

LEGEND

|—•—| Sampled every 15 min between indicated limits

|—▭—| Sampled every minute during enclosed time

▨ Gas chromatograph atmospheric & subsurface gas analysis

▮ Spectroradiometer Part 2 operation

ample 3   Sample 4

4

15   16   17   18   19   20   21   22   23   24   25   26   27   28   29   30   31   32

e from Touchdown – Hours

14.1-3-2

a. Sterilization,

b. Low power consumption,

c. Hard vacuum space environment,

d. Life,

e. Reliability,

f. Satisfactory operation after a long dormancy,

the SL SDS has data and control oriented requirements and constraints. These are:

a. Reprogrammable experiment sequencing for mission flexibility,

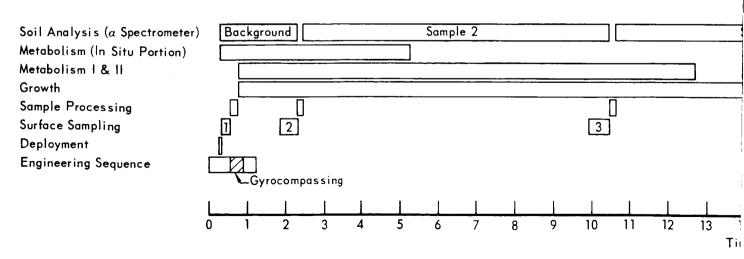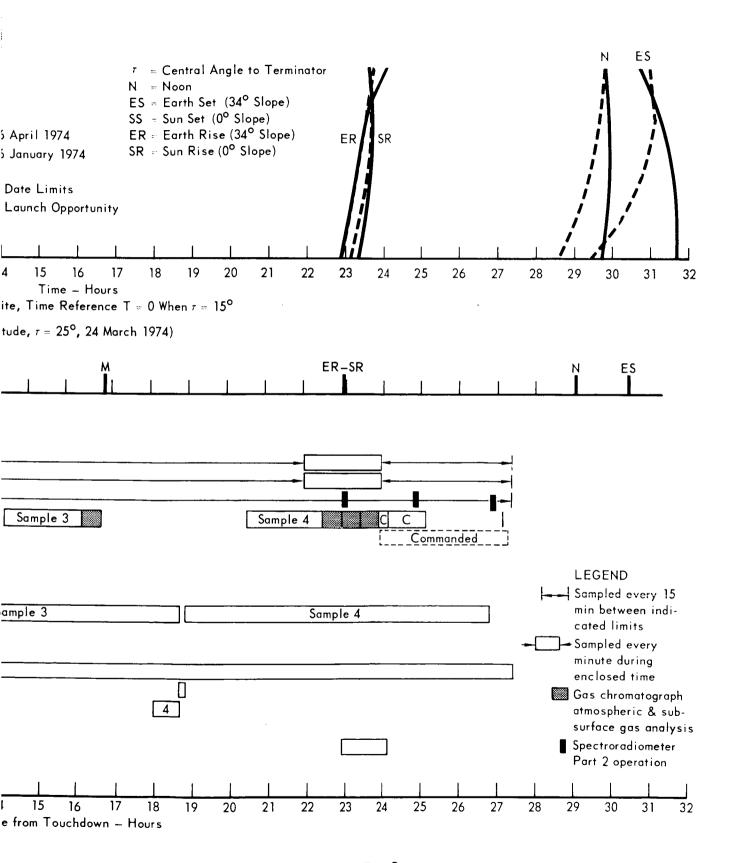b. Modularized SDS to minimize the impact of experiment redefinition on designed and/or qualified hardware,

c. DC isolation of all digital interfaces - reducing ground loop vehicle noise,

d. Usage of alternate functional, paths as opposed to block redundancy,

e. Graceful degradation.

14.1.3 <u>Physical Characteristics</u> - The SL SDS occupies 200 cubic inches, weighs 10 pounds, and requires 11.5 watts. Note that the estimated weight is significantly less than the 20 pounds specified in the JPL Constraints Document. This is because science instrument on-off and mode selection control as well as temporary data storage is provided by the reprogrammable core memory of the SL TM programmer. This approach reduces the weight of the SDS but increases the weight of the SL TM. The net result, however, is an overall savings in total weight.

14.1.4 <u>Operational Description</u> - The operational description is divided into two parts. The first describes the modes of operation of the equipment in terms of the mission phase. The second part describes the functions of the principal components.

14.1.4.1 <u>Operational Modes</u> - The SL SDS will experience 4 modes: launch and interplanetary cruise, in-flight checkout, deorbit/entry, and landed data acquisition.

    o <u>Launch and Interplanetary Cruise</u> - During this mode science instruments and the SDS are dormant, thus only a small amount of status information is required. The status information is monitored by the SL TM cruise commutator and transferred to the Capsule Bus (CB) for subsequent transmission to Earth by the Flight Spacecraft(FSC).

    o <u>In-Flight Checkout Mode</u> - During this mode all of the science instruments will be tested prior to separation. The SDS has a checkout mode to support checkout of the instruments. The data acquisition and transfer rates will be the normal rates but the total amount of data transferred

14.1-4

will be reduced by only transferring a limited number of data frames. The data acquisition formats are the same as for the Landed Data Acquisition Mode and are shown in Figure 14.1-3.

o <u>Deorbit/Entry</u> - As in the launch and cruise mode, the science instruments as well as the SDS are dormant, thus only status information is required. The status information is monitored by the SL TM cruise commutator and transferred to the CB for subsequent transmission to Earth.

o <u>Landed Data Acquisition Mode</u> - In this mode the SDS must initiate science instrument operation, provide all sequencing commands necessary to perform each experiment, acquire data from each instrument, and transfer the acquired data to the SL TM.

14.1.4.2 <u>Component Description</u> - The SDS is in reality a group of 9 modules (Remote Interface Units) assembled as a package and serving as interfacing devices between the SL TM and the science instruments. Each instrument has a unique RIU designed to meet its specific operating requirements and presenting a standardized interface to the SL TM. The actual sequence by which the experiments are run is stored in the reprogrammable SL TM memory. The TM programmer compares vehicle time with stored control words and, when comparison is achieved, a signal is addressed to the appropriate RIU to initiate operation of a specific instrument in a particular mode. RIU proceeds from that point providing all signals (commands and data interrogations in proper time phase) necessary to complete that measurement and acquire the data. The data is transferred to the SL TM for storage either in the TM core memory or, in the case of imaging data, the DSS tape recorder. Data acquisition formats for each RIU are shown in Figure 14.1-3. RIU's for each experiment are described below.

o <u>Visual Imaging RIU</u> - A functional block diagram of the Visual Imaging RIU is presented in Figure 14.1-4. Required experiment commands are indicated at the left of the diagram. Several status commands which must be transmitted to the RIU, are generated by the imaging system. These include three short-pulse outputs (mode complete, data ready, and end of line) which trigger the RIU status flip-flops. Two other status commands (dust inhibit and light level inhibit) will be continuous-pulse. Science and engineering data are handled separately in this experiment. Due to the large quantity of science data, the ten parameters shown in the block diagram are multiplexed and transferred to the SL TM equipment. The three
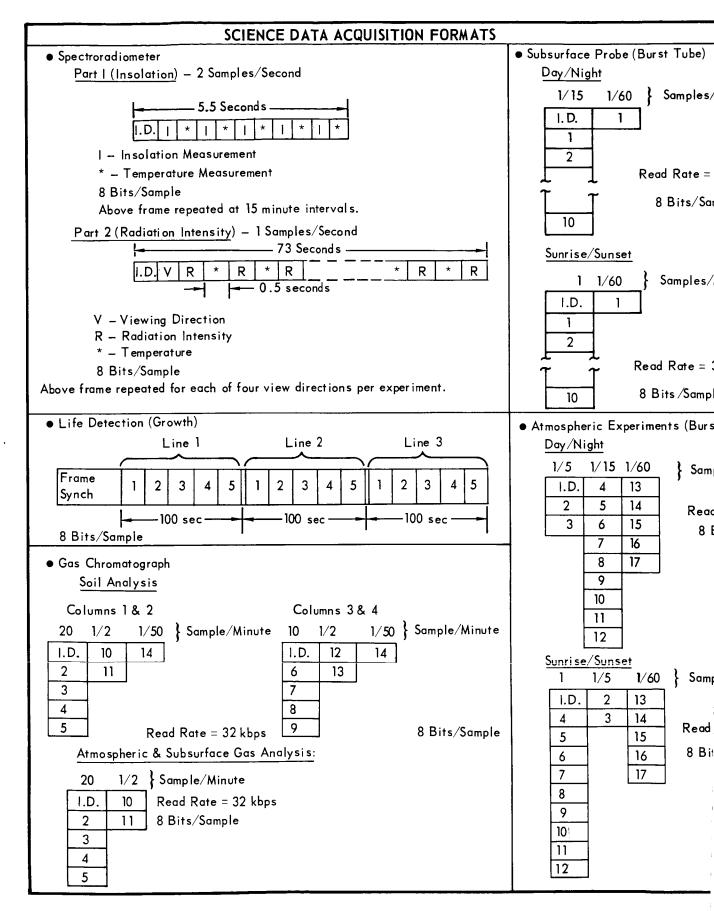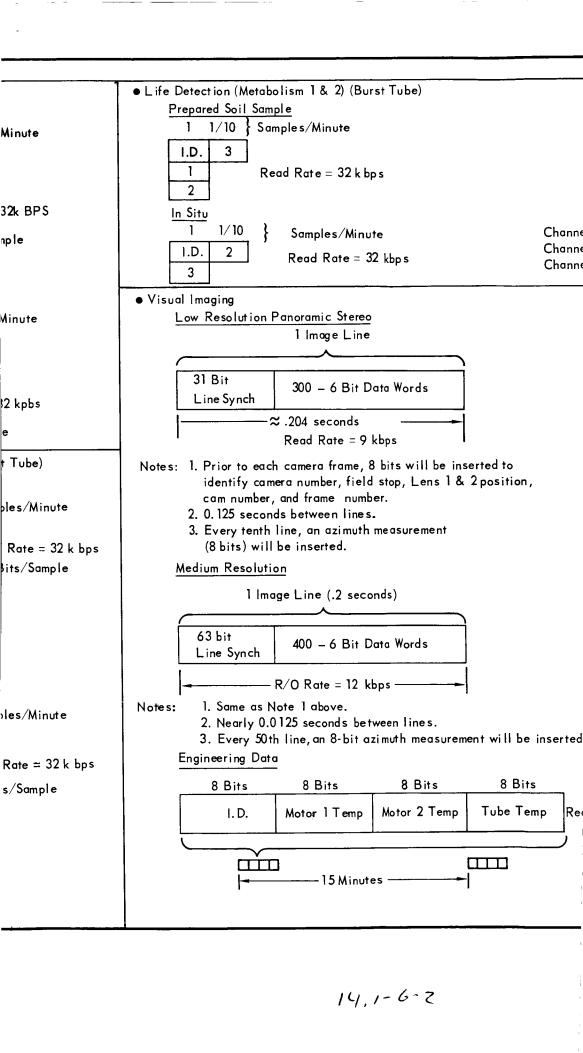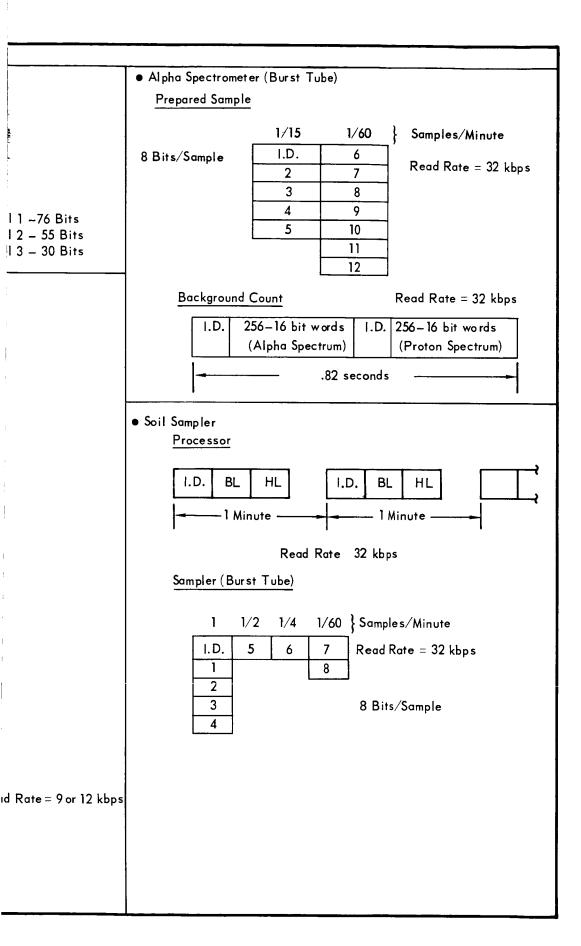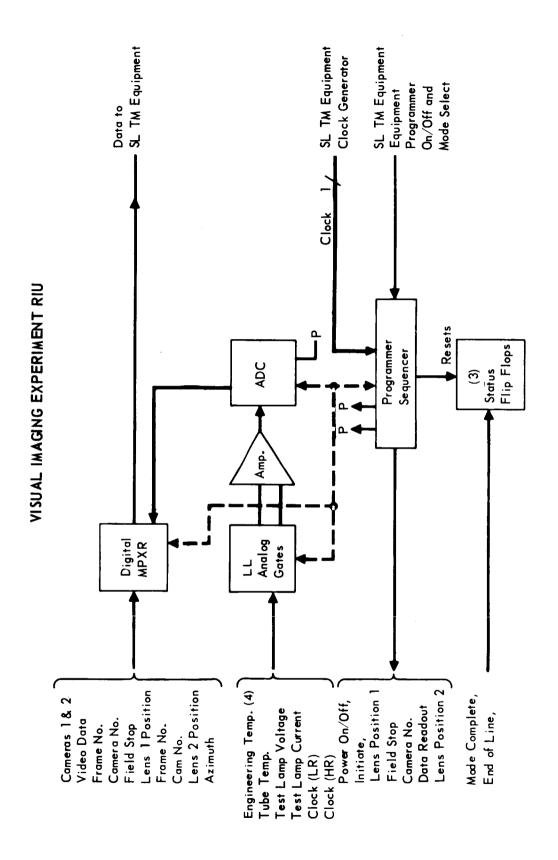
SCIENCE DATA ACQUISITION FORMATS

- **Spectroradiometer**

  <u>Part I (Insolation)</u> – 2 Samples/Second

  |← 5.5 Seconds →|
  | I.D. | I | * | I | * | I | * | I | * | I | * |

  I – Insolation Measurement

  * – Temperature Measurement

  8 Bits/Sample

  Above frame repeated at 15 minute intervals.

  <u>Part 2 (Radiation Intensity)</u> – 1 Samples/Second

  |← 73 Seconds →|
  | I.D. | V | R | * | R | * | R | — — — | * | R | * | R |

  |← 0.5 seconds →|

  V – Viewing Direction

  R – Radiation Intensity

  * – Temperature

  8 Bits/Sample

  Above frame repeated for each of four view directions per experiment.

- **Life Detection (Growth)**

  | Frame Synch | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |

  Line 1   Line 2   Line 3

  |←—100 sec—→|←—100 sec—→|←—100 sec—→|

  8 Bits/Sample

- **Gas Chromatograph**

  <u>Soil Analysis</u>

  Columns 1 & 2

  20   1/2   1/50 } Sample/Minute

I.D.	10	14
2	11	
3		
4		
5		

  Columns 3 & 4

  10   1/2   1/50 } Sample/Minute

I.D.	12	14
6	13	
7		
8		
9		

  Read Rate = 32 kbps

  8 Bits/Sample

  Atmospheric & Subsurface Gas Analysis:

  20   1/2 } Sample/Minute

I.D.	10
2	11
3	
4	
5	

  Read Rate = 32 kbps

  8 Bits/Sample

- **Subsurface Probe (Burst Tube)**

  Day/Night

  1/15   1/60 } Samples/

I.D.	1
1	
2	
10	

  Read Rate =

  8 Bits/Sar

  <u>Sunrise/Sunset</u>

  1   1/60 } Samples/

I.D.	1
1	
2	
10	

  Read Rate = 3

  8 Bits/Sampl

- **Atmospheric Experiments (Burst**

  Day/Night

  1/5   1/15   1/60 } Sam

I.D.	4	13
2	5	14
3	6	15
	7	16
	8	17
	9	
	10	
	11	
	12	

  Read

  8 E

  <u>Sunrise/Sunset</u>

  1   1/5   1/60 } Samp

I.D.	2	13
4	3	14
5		15
6		16
7		17
8		
9		
10		
11		
12		

  Read

  8 Bit

Figure 14.1-3

14.1-6

Life Detection (Metabolism 1 & 2) (Burst Tube)

Prepared Soil Sample

1   1/10 } Samples/Minute

I.D.	3
1	
2	

Read Rate = 32 k bps

In Situ

1   1/10 } Samples/Minute

I.D.	2
3	

Read Rate = 32 kbps

Channe
Channe
Channe

Visual Imaging

Low Resolution Panoramic Stereo

1 Image Line

31 Bit Line Synch	300 – 6 Bit Data Words

≈ .204 seconds
Read Rate = 9 kbps

Notes:
1. Prior to each camera frame, 8 bits will be inserted to identify camera number, field stop, Lens 1 & 2 position, cam number, and frame number.
2. 0.125 seconds between lines.
3. Every tenth line, an azimuth measurement (8 bits) will be inserted.

Medium Resolution

1 Image Line (.2 seconds)

63 bit Line Synch	400 – 6 Bit Data Words

R/O Rate = 12 kbps

Notes:
1. Same as Note 1 above.
2. Nearly 0.0125 seconds between lines.
3. Every 50th line, an 8-bit azimuth measurement will be inserted

Engineering Data

8 Bits	8 Bits	8 Bits	8 Bits	
I.D.	Motor 1 Temp	Motor 2 Temp	Tube Temp	Re

|← 15 Minutes →|

Minute

32k BPS
nple

Minute

32 kpbs
le

t Tube)

les/Minute

Rate = 32 k bps
its/Sample

les/Minute

Rate = 32 k bps
s/Sample

Alpha Spectrometer (Burst Tube)

Prepared Sample

8 Bits/Sample

	1/15	1/60
	I.D.	6
	2	7
	3	8
	4	9
	5	10
		11
		12

} Samples/Minute

Read Rate = 32 kbps

Background Count   Read Rate = 32 kbps

I.D.	256 – 16 bit words (Alpha Spectrum)	I.D.	256 – 16 bit words (Proton Spectrum)

|← ——————— .82 seconds ——————— →|

Soil Sampler

Processor

I.D.	BL	HL		I.D.	BL	HL			

|← —— 1 Minute —— →|← —— 1 Minute —— →|

Read Rate   32 kbps

Sampler (Burst Tube)

	1	1/2	1/4	1/60
	I.D.	5	6	7
	1			8
	2			
	3			
	4			

} Samples/Minute

Read Rate = 32 kbps

8 Bits/Sample

I 1 –76 Bits
I 2 – 55 Bits
I 3 – 30 Bits

d Rate = 9 or 12 kbps

VISUAL IMAGING EXPERIMENT RIU

Figure 14.1-4

14.1-7

low-rate, low-volume engineering parameters (temperatures) are sampled, amplified and encoded in the RIU prior to transfer to the SL TM Equipment. The data acquisition formats for this experiment are shown in Figure 14.1-3.

o <u>Atmospheric Properties RIU</u> - The block diagram for this RIU is shown in Figure 14.1-5. Commands required by this experiment are indicated in the bottom left hand corner of the block diagram. On-off commands will be generated by a flip-flop and the remaining five commands by one-shot multi-vibrators.   No status commands are generated by this experiment. The data acquisition formats are shown in Figure 14.1-3.

o <u>Soil Analysis (Alpha Spectrometer) RIU</u> - Operation of this experiment re-quires six short-duration, pulse-type commands as shown in the bottom left-hand corner of Figure 14.1-6. In addition, alpha and proton accumulator readout requires that each accumulator be addressed directly; thus neces-sitating a total of 512 9-bit commands which will be transferred in parallel from the RIU programmer. This programmer is a simple binary counter oper-ating at 32 kHz. The "start count" command will be initiated by the SL TM programmer. The "start count" command will be used to switch the RIU output data line from the position shown in Figure 14.1-6 to the "data ready" position.

There are two RIU data acquisition modes, the engineering mode which is active during an experiment and the spectrum (accumulator) readout mode following completion of an experiment. Data acquisition formats for this experiment are shown in Figure 14.1-3.

o <u>Gas Analysis (Gas Chromatograph) RIU</u> - A functional block diagram of this RIU is shown in Figure 14.1-7. Both power on and power off signals are pulses that drive a latching relay which controls the power. The mode-selection signals are three binary-coded lines which select one of five modes in the chromatograph equipment. A single "analysis complete" signal is received when the experiment is concluded.

Four experiment parameters and three engineering parameters are low-level signals and eight experiment parameters are high-level signals. Each parameter is selected by the RIU sequencing programmer and a convert signal starts the conversion of each parameter to a digital value. Data acquisition formats are shown in Figure 14.1-3.

o <u>Life Detection (Metabolism 1 and 2) RIU</u> - The functional block diagram is shown in Figure 14.1-8. Five short, pulse type commands are required by
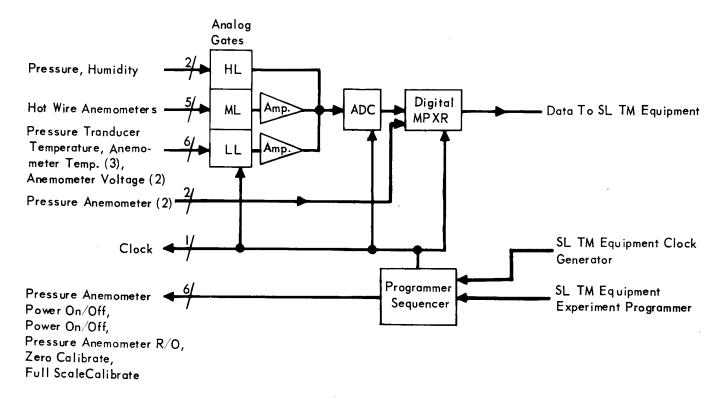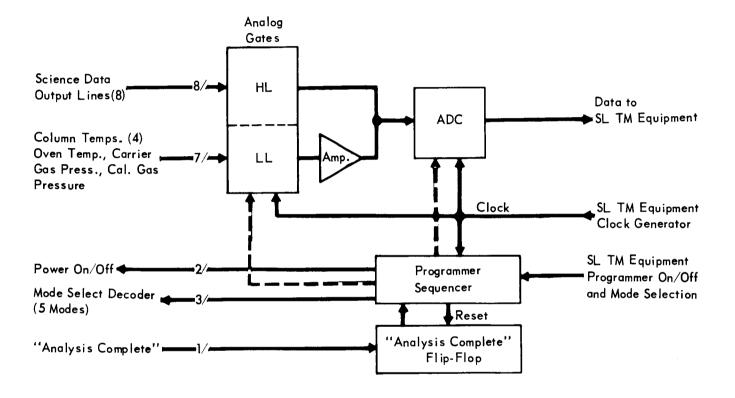
ATMOSPHERIC PROPERTIES EXPERIMENT RIU

Analog
Gates

Pressure, Humidity —2/→ HL

Hot Wire Anemometers —5/→ ML [Amp.] → ADC → Digital MPXR → Data To SL TM Equipment

Pressure Tranducer
Temperature, Anemo-
meter Temp. (3), —6/→ LL [Amp.]
Anemometer Voltage (2)

Pressure Anemometer (2) —2/→

Clock ←1/

SL TM Equipment Clock Generator

Programmer Sequencer

Pressure Anemometer ←6/
Power On/Off,
Power On/Off,
Pressure Anemometer R/O,
Zero Calibrate,
Full ScaleCalibrate

SL TM Equipment
Experiment Programmer

Figure 14.1–5

14.1–9

SOIL ANALYSIS (ALPHA SPECTROMETER) EXPERIMENT RIU

Figure 14.1-6

14.1-10

GAS ANALYSIS (GAS CHROMATOGRAPH) EXPERIMENT RIU

Analog
Gates

Science Data
Output Lines(8) ——— 8/→ | HL | → ADC → Data to
SL TM Equipment

Column Temps. (4)
Oven Temp., Carrier ——— 7/→ | LL | Amp.
Gas Press., Cal. Gas
Pressure

Clock ——— SL TM Equipment
Clock Generator

Power On/Off ◄——— 2/ | Programmer | ◄——— SL TM Equipment
Sequencer | Programmer On/Off
and Mode Selection
Mode Select Decoder ◄——— 3/
(5 Modes)

Reset

"Analysis Complete" ——— 1/——— → | "Analysis Complete" |
Flip-Flop

Figure 14.1-7

14.1-11

LIFE DETECTOR (METABOLISM 1 & 2) EXPERIMENT RIU

this experiment; power on/off, start, read, and recycle. The latter command is transmitted by the RIU upon receipt of a status command from the experiment, indicating completion of the preceding cycle. There are two data lines from the experiment to the RIU. The first, containing science data, is sampled once every minute throughout the 12-hour experiment. The 104 data bits are read out at 32,768 bps. The second line, containing engineering data is sampled once every ten minutes. These 55 bits also are read out at 32,768 bps. The data formats are illustrated in Figure 14.1-3.

o <u>Life Detection (Growth) RIU</u> - Figure 14.1-9 is a block diagram for this RIU. All commands from this RIU are pulses. The "recycle" command duration is in the millisecond range while the "step commutator" and "switch output lines" commands are gated clocks. A single response is obtained from the experiment equipment (cycle complete) indicating the end of a data generation cycle.
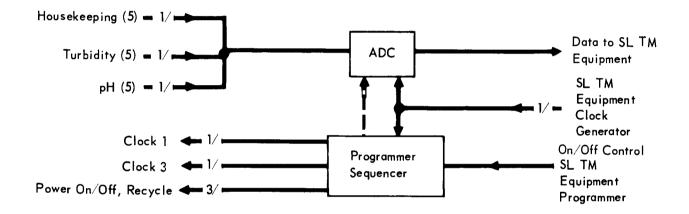
Three lines carry the commutated data to the A-D converter. Only one line is active at a time and a sequence of five high-level measurements are received over a 100-second period. Data from the A-D converter is transferred serially at 32,768 bps to the SL TM Equipment. No data commutation capability is required in this RIU. Data acquisition formats are shown in Figure 14.1-3.

o <u>Subsurface Probe RIU</u> - Four decoded commands provide constant-level outputs (unstow, deploy, zero calibrate, full-scale calibrate). The remainder of decoded signals are pulses whose duration is selected to match the requirements of the equipment operated by the pulse. For example, the temperature power on/off control will be a latching relay so that no power is consumed holding the relay on. The pulse width of these signals is about 10 milliseconds. The "temperature-data sample" signal is used to step a multiplexer in the experiment.

Three control responses are received from the experiment equipment (unstow complete, deploy complete and pump-cycle complete). These signals are pulses that set flip-flops in the status Command Encoder.

Experiment data is multiplexed by the experiment equipment so that the ten samples appear sequentially on a single line. This line is connected to a low-level analog gate and subsequently to an amplifier. An engineering parameter also is gated into the amplifier. The amplifier output provides the input to the A-D converter which operates on command from the RIU sequencer

14.1-13

LIFE DETECTION (GROWTH) EXPERIMENT RIU
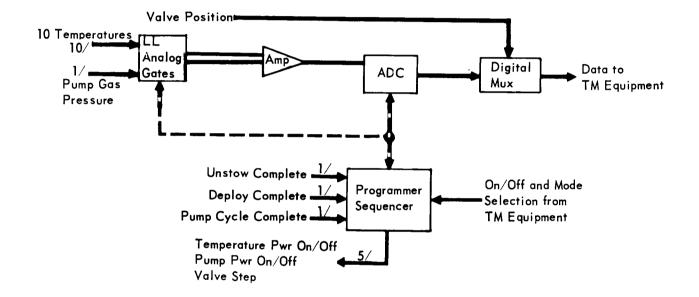
programmer. A functional block diagram is shown in Figure 14.1-10. The data acquisition formats are shown in Figure 14.1-3.

o <u>Spectroradiometer RIU</u> - Figure 14.1-11 presents a block diagram of this RIU. Three short, pulse-type commands are required by this experiment (power on, power off and sample). The latter command is transmitted by the RIU sequencer programmer upon receipt of a status command (pointing complete) from the experiment. To provide pointing information for the experiment, an appropriate binary-coded command will be generated in the sequencer programmer and relayed serially through the RIU Command Store and Decode Unit.

Eight output data lines are provided by the experiment. Four of these lines are required for the spectrum scanning measurements and will be sampled sequentially following receipt of the "sample" command. Data on each line will contain multiplexed samples from forty parameters to an 8-bit encoding accuracy requirement. A 4-bit tag will be added to each encoded word at the ADC output. The total insulation output line is sampled at 15-minute intervals and encoded to 8 bits. Three 8-bit temperature measurements also are required at 15-minute intervals. All data samples will be transferred from the RIU at 32,768 bps. The data acquisition formats are illustrated in Figure 14.1-3.

o <u>Soil Sampler and Processor RIU</u> - The functional block diagram for this RIU is shown in Figure 14.1-12. In this RIU five command pulses are generated. Among these five commands is a signal for sample density value readout. Three additional commands are binary-coded bit streams (sampler azimuth: 7 bits, foot position: 4 bits and sample override: 2 bits). Seven control responses to the commands are generated as pulses that set flip-flops in the Status Command Encoder. Five of the READY signals indicate that samples are ready for analysis in other experiments (i.e., alpha spectrometer, gas chromatograph, Wolf trap and two Gulliver experiments).

Two experiment parameters and one engineering parameter produce low-level analog signals. Five experiment parameters produce high-level analog signals and the remaining six measurements are bilevel signals. Coordination of A-D conversion with multiplexing is facilitated by a convert signal generated concurrently with the sampling signal. The data acquisition formats are shown in Figure 14.1-3.
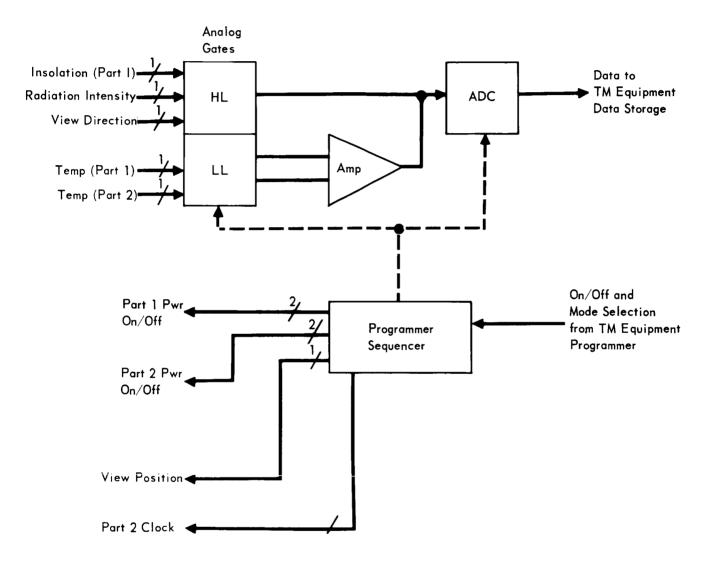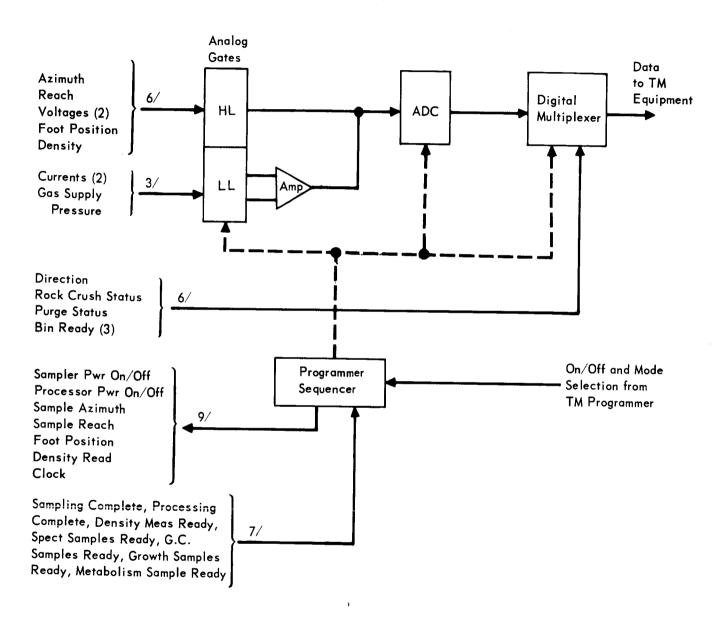
SUBSURFACE PROBE RIU

Valve Position

10 Temperatures
10/

LL Analog Gates

1/
Pump Gas Pressure

Amp

ADC

Digital Mux

Data to TM Equipment

Unstow Complete 1/
Deploy Complete 1/
Pump Cycle Complete 1/

Programmer Sequencer

On/Off and Mode Selection from TM Equipment

Temperature Pwr On/Off
Pump Pwr On/Off
Valve Step

5/

SPECTRORADIOMETER RIU

Figure 14.1-11

14.1-17

SOIL SAMPLE ACQUISITION RIU

14.1.5 Performance Characteristics

a. Input Signals

o Single ended high level 0-5V

o Dougle ended low level 0-40 mv maximum of 10V common mode

o Double ended low level 0-120 mv maximum of 10V common mode

o Logic level digital inputs -0 or 5V

o Nonlogic level bilevel 0 or 28V

b. Conversion Accuracy

o Single ended high level ± 1 count in 254

o Double ended low level ± 2 counts in 254

o Logic level digital, 1 error in 10^5

o Non-logic level bilevel, 1 error in 10^3 with less than 1V or a "space" and greater than 4V as a mark

c. Output Signals

o All digital, 0 or 5V, 5K ohm

o Straight binary encoded NRZ zero and full scale suppression out of ADC's

d. Programming

o Interlaced or burst tube formatting for all programs

e. General

o Analog switching action is independent of source impedance

o DC isolation in all digital interfaces

o Signal, power and chassis isolation

o Vehicle time in each frame

14.1.6 Interfaces - The interfaces are given in Figure 14.1-13.

14.1.7 Reliability - The SDS Equipment Reliability Model, Fault Tree and Complexity Estimate are shown in Figures 14.1-14, 14.1-15, and 14.1-16 respectively. The estimated reliability for the SDS is .987. The SDS design is characterized by multi-channel cooperative redundancy by decentralization of Remote Interface Functions. This feature enhances partial data retrieval probability in the event individual failures occur. Due to the relative independence of the Remote Interface Units from each other in lieu of one single complex RIU, probability of partial mission success is improved to .998 for the SDS. No special safety provisions are required because there are no high voltage applications in the subsystem.

SURFACE LABORATORY SCIENCE DATA SUBSYSTEM INTERFACE MATRIX

	Visual Imaging Instrument	Atmospheric Properties Instruments	Soil Analysis Instrument	Gas Analysis Instrument	Life Detection (Metabolism) Instrument	Life Detection (Growth) Instrument	Subsurface Probe Instruments	Spectroradiometer	Soil Sampler & Processor	DC Power Bus	SL TM	S & T
Visual Imaging RIU	X										X	
Atmospheric Properties RIU		X									X	
Soil Analysis RIU			X								X	
Gas Analysis RIU				X							X	
Life Detection (Metabolism) RIU					X						X	
Life Detection (Growth) RIU						X					X	
Subsurface Probe RIU							X				X	
Spectroradiometer RIU								X			X	
Soil Sampler & Processor RIU									X		X	
DC to DC Converter										X		

Figure 14.1–13

14.1–20

VOYAGER SURFACE LABORATORY SCIENCE DATA SUBSYSTEM RELIABILITY MODEL

Figure 14.1-14

14.1-21
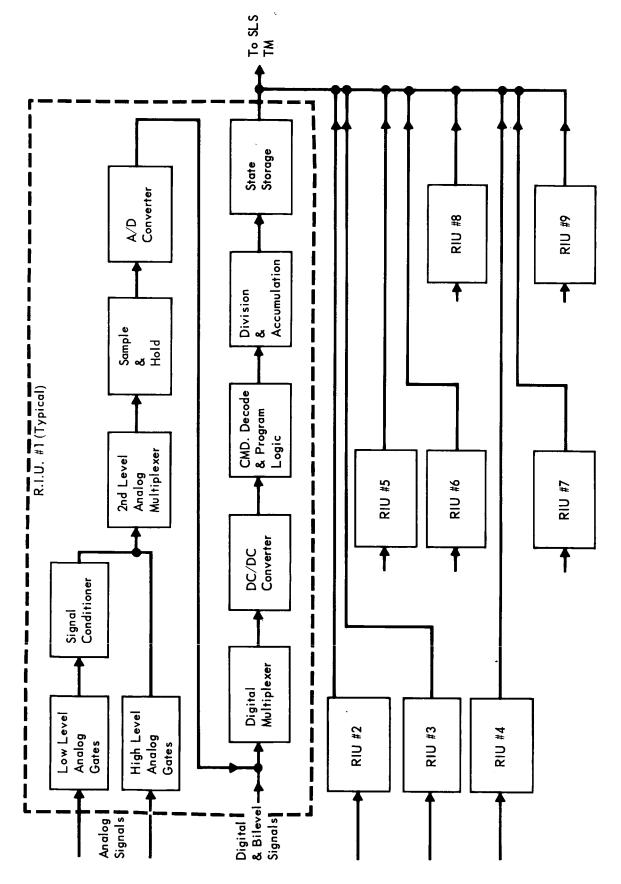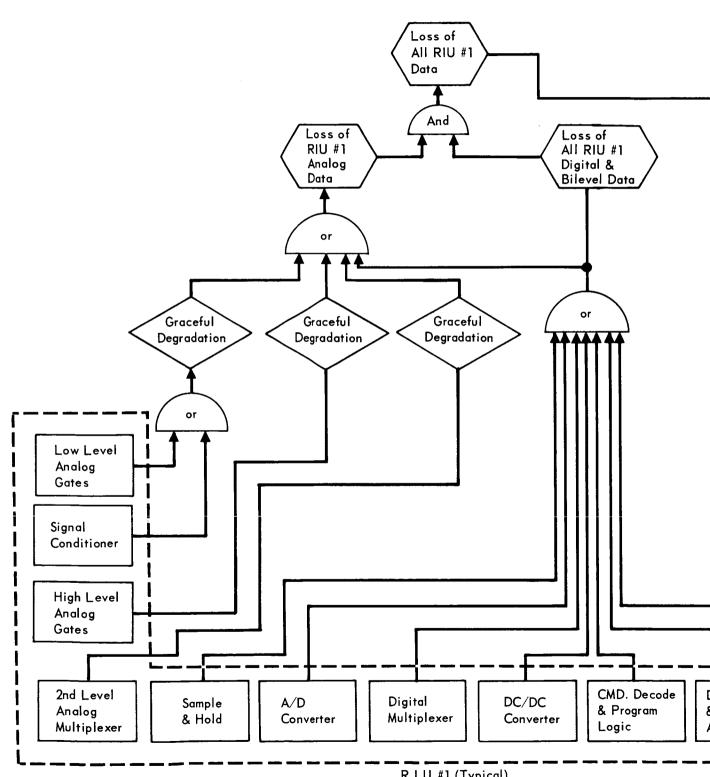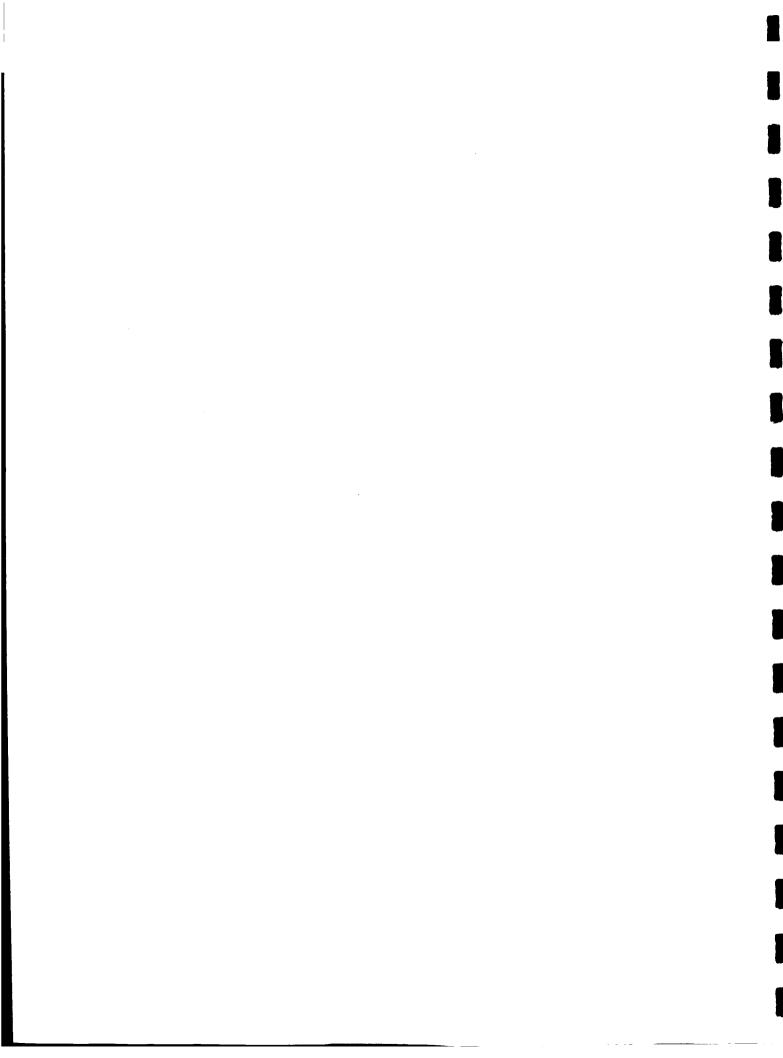
VOYAGER SURFACE LABORATORY SCIENCE DATA SUBSYSTEM RELIABILITY FAULT TREE
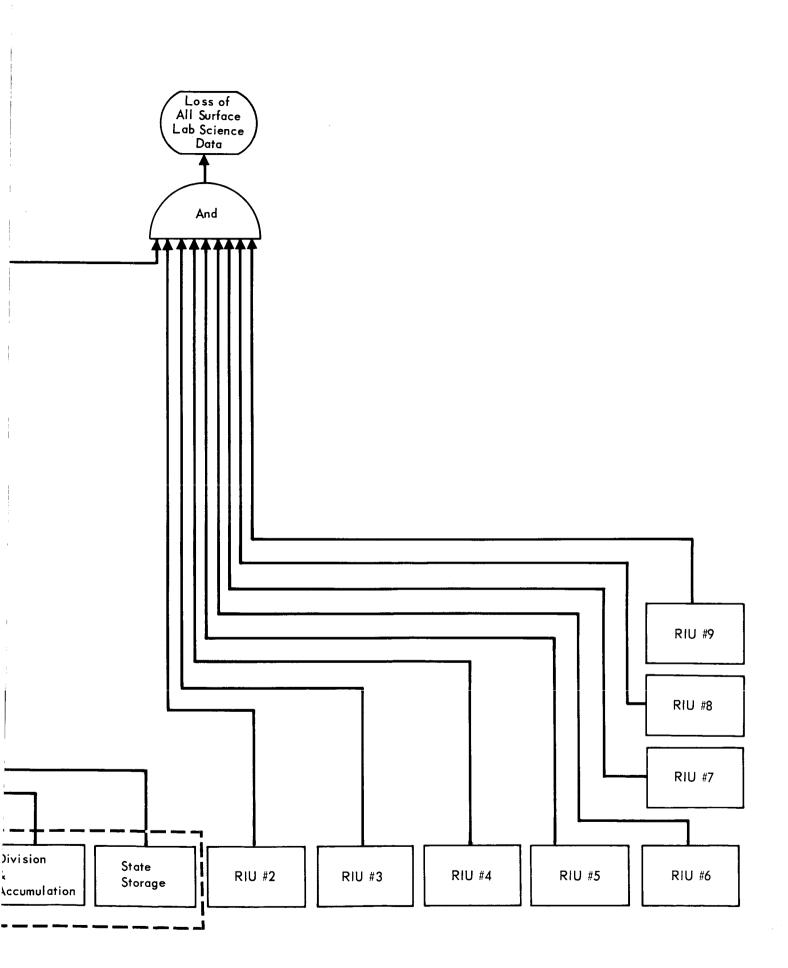
R.I.U #1 (Typical)

Figure 14.1–15

14.1–22 ⸝ /

Loss of All Surface Lab Science Data

And

RIU #9
RIU #8
RIU #7

Division
Accumulation
State Storage
RIU #2
RIU #3
RIU #4
RIU #5
RIU #6

14.1-22-2

PART TYPE	FAILURE RATE, BITS (10^{-8} failures per hour)	QUANTITY	TOTAL FAILURE RATE, BITS (10^{-8} failures per hour)
Integrated Circuits			
Digital	10	1228	12280
Linear	30	108	3240
Transistors:			
General Purpose	5.0	18	90
Power	5.0	36	1800
Diodes:			
General Purpose	1.1	72	79.2
Zener	10	18	180
Resistors:			
Metal Film	0.3	570	171
Ladder Network	9.6	24	240.4
Capacitors:			
Ceramic	1.0	276	276
Solid Tantalum	2.0	180	360
Mylar	0.5	24	12.0
Inductors, Low Voltage	10	18	180
Transformer, Low Voltage	5.0	9	45
TOTALS		2581	18953.6

Figure 14.1-16

14.1-23

14.1.8 _Test_ - All of the science instruments are tested through the SDS during the test build-up from factory tests through lift-off. During the Mars orbit in-flight checkout mode, all of the science instruments are tested through the SDS. Prior to any of the using science instrument tests the SDS is tested. The SDS tests are conducted in a checkout mode. See Figure 14.1-17.

The SDS tests are principally directed toward the major functional blocks following a specific data "chain". Each "chain" is identified by a block of signal types, e.g., a low level calibration signal(s) is injected to a low level gate and the output of the SDS (at the TM input) is monitored. This tests the chain of low level signals, namely, the gates and gate driver programming, the differential amplifier, and the digital multiplexer. Note that each individual gate is not tested (in-flight) but all of the major functional blocks are tested. Factory testing tests each gate, while the individual gates are tested in flight when monitoring the science instruments.
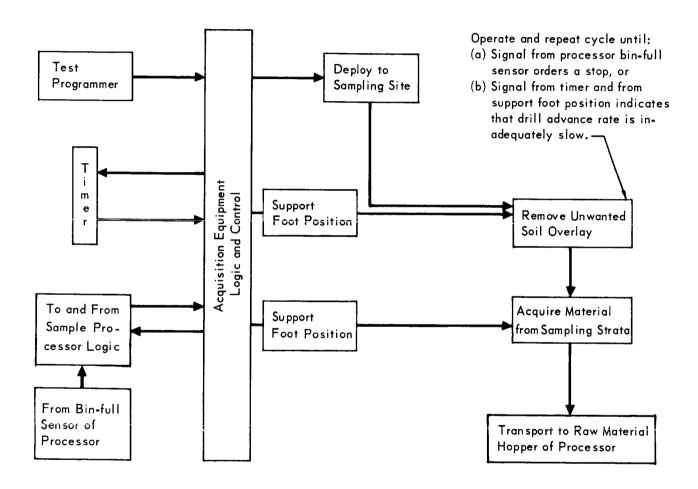
14.1.19 _Development Status_ - Aside from the normal VOYAGER development requirements, specifically reliability and sterilization, the SL SDS will not require any state-of-the-art advances.

SCIENCE DATA SUBSYSTEM TEST MATRIX

ACCY REQ.	TEST	Telemetry	System Test (Pre-Canister)	System Test (With Canister)	Pre-Launch	In-Flight Checkout
2%	Output Voltage	●	●	●	●	●
	DC–DC Converter					
Digital	Output Signals		●	●	●	●
Digital	Input Signals		●	●	●	●
	Remote I/F Units					
1%	A/D Calibration Signals	●	●	●	●	●
1%	Input Calibration Signals	●	●	●	●	●
	Data ADC/Multiplexer					
Digital	Memory Control Signals		●			
Digital	Output Signals		●	●	●	●
Digital	Input Data		●			
	Instruction Storage					
Digital	Output Commands		●	●	●	
Digital	Input Command Data		●			
	Instruction Logic					
	Non Operative Test					

Figure 14.1–17

14.1–25

14.2 SAMPLE ACQUISITION AND PROCESSING EQUIPMENT - The sample acquisition and processing equipment consists of: (1) the surface sample acquisition equipment, a boom-mounted device capable of collecting solid surface and shallow subsurface samples using an auger drill, (2) a processing unit which takes the raw material coming out of the surface sample acqusition device and screens the samples to obtain 0 to 200 μ, 0 to 500 μ, and 50 to 500 μ graded samples for the science instruments and (3) a subsurface probe mechanism which is the acquisition device for collecting gases trapped below the surface. The subsurface probe also includes thermocouple instrumentation for measuring subsurface temperatures. The thermocouple instrumentation is discussed separately in Section 14.3.10.

14.2.1 Surface Sample Acquisition Equipment - This equipment consists of a boom-mounted surface sample acquisition device which collects soil samples at various locations. These samples are transferred to the mechanical processor within the surface laboratory for eventual distribution to the science subsystem instruments for analysis. The functions of the equipment are described in Figure 14.2-1.
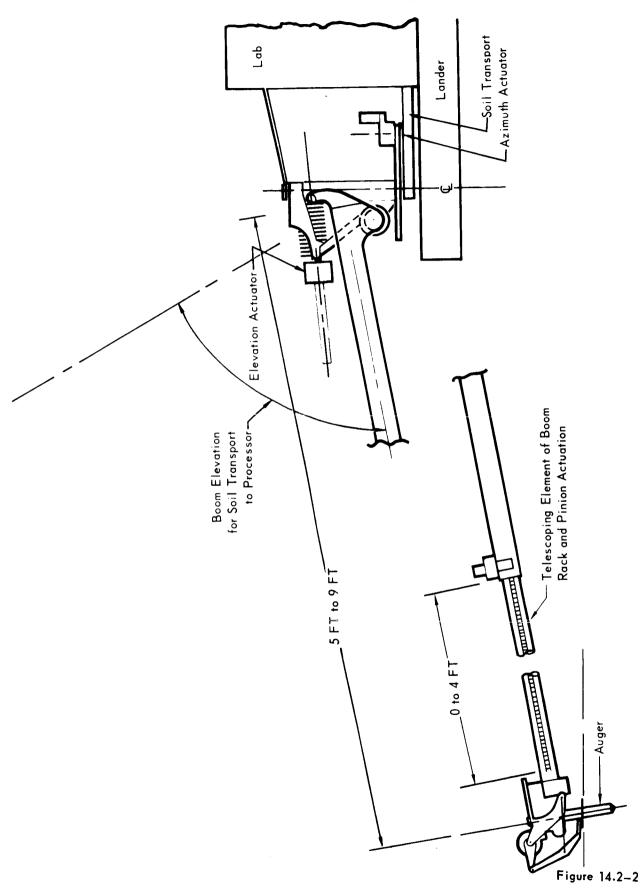
14.2.1.1 Equipment Identification and Usage - The surface sample acquisition equipment is comprised of the following major component assemblies:

a. Sample acquisition head

b. Boom

c. Boom support assembly including elevation and azimuth actuators

d. Material conveyor

e. Logic and control

o Sample Acquisition Head - The sample acquisition head is basically an auger surrounded by a casing. The auger is capable of retracting at successive intervals to remove accumulated materials. The sample acquisition head has the following characteristics:

a. Capability for boring an 0.80 inch diameter hole

b. Acquisition capability for hardness of soil structure equivalent to hardpan as well as loose particle gathering

c. Range of elevation angle travel from 50 degrees downward to 70 degrees upward from the Surface Laboratory base plane.

o Boom and Boom Support Assembly - The boom provides support for and positioning of the sample acquisition head. The boom has the following characteristics:

a. Provides a minimum of 120 degrees of lateral sweep for positioning

b. Effective length adjustable from five to nine feet

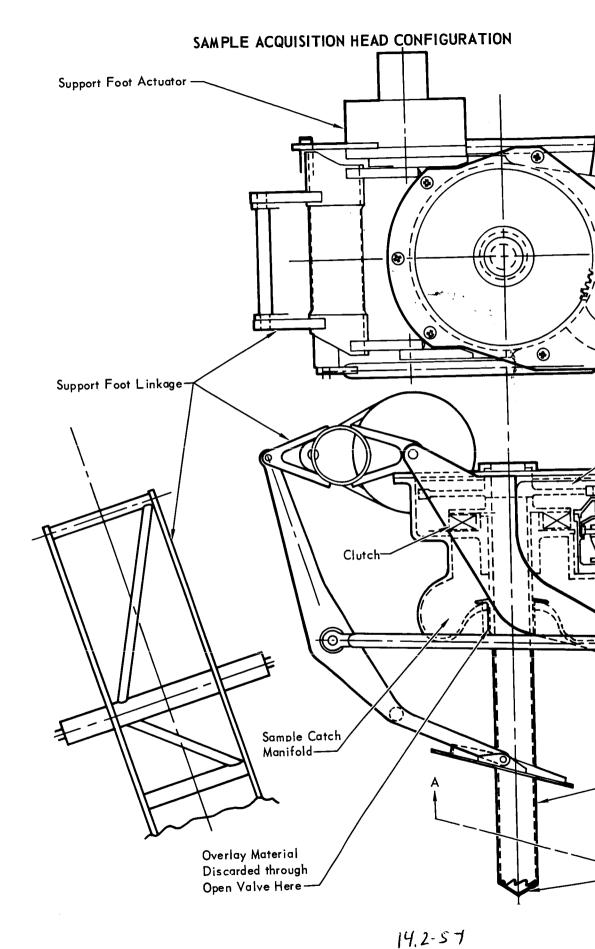## SAMPLE ACQUISITION EQUIPMENT
(FUNCTIONAL BLOCK DIAGRAM)

Operate and repeat cycle until:
(a) Signal from processor bin-full sensor orders a stop, or
(b) Signal from timer and from support foot position indicates that drill advance rate is inadequately slow.

Test Programmer

Timer

To and From Sample Processor Logic

From Bin-full Sensor of Processor

Acquisition Equipment Logic and Control

Deploy to Sampling Site

Support Foot Position

Support Foot Position

Remove Unwanted Soil Overlay

Acquire Material from Sampling Strata

Transport to Raw Material Hopper of Processor

Figure 14.2-1

14.2-2

o   Material Conveyor - The material conveyor tube delivers the acquired
     samples to the processing equipment. The head is lifted above the
     surface so that the collected sample will slide down the conveyor tube to
     the processor.

o   Internal Control - The internal control consists of the signal gener-
     ation and closed loop control required for changing sites when hard
     material is encountered and for stopping the acquisition operation when
     a bin full signal is received from the processor.

14.2.1.2 Design Requirements and Constraints - The surface sample acquisition
equipment design requirements and constraints are:

a. Minimum destruction of life forms

b. Accomplishing its tasks within view of one of the cameras

c. Acquiring required sample quantities, 380 cm³, at minimum power consump-
     tion

d. Sample outputs from the acquisition equipment must be suitable for pro-
     cessing. (The processor must provide a total of 92 cm³ of graded samples
     in size ranges of 0 to 500 μ, 0 to 200 μ, and 50 to 500 μ.)

e. Maximum assurance of soil material being acquired

f. Suitable for use in acquiring materials of different textures, such as
     loose materials and conglomerates of 250 psi crushing strength.

14.2.1.3 Physical Characteristics - The configuration of the surface sample
acquisition equipment which has a total weight of 16 pounds is shown in Figure
14.2-2 and 14.2-3.

14.2.1.4 Operation Description - The surface sample acquisition equipment is
deployed using an electrical impulse from the electro-explosive device (EED)
control module (Section 6.0) to the pyrotechnic release tie-down clamp. Prepro-
grammed commands drive the azimuth and elevation actuators to position the
sample acquisition head for drilling. After positioning the head, the elevation
actuator applies a downward force to the drill head for drilling. After the
auger penetrates the overlay strata the auger is raised, and the material gathered
is ejected belowthe manifold through a dump valve. Sample acquisition is then
initiated by boring to a depth below the surface level (10 cm max.) and depos-
iting the material in the sample catch manifold. Upon completion of drilling
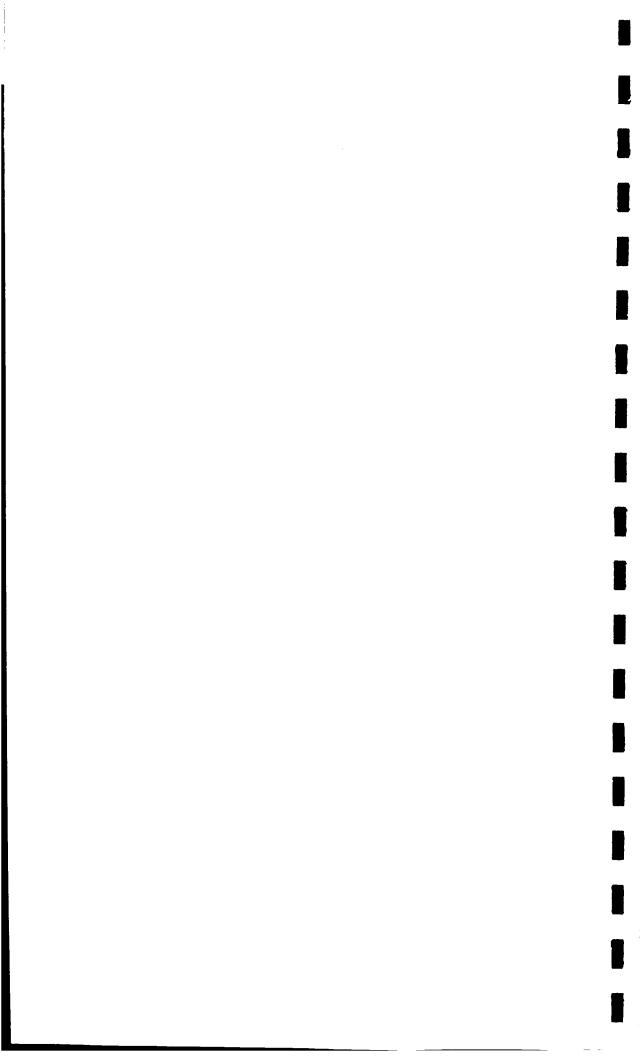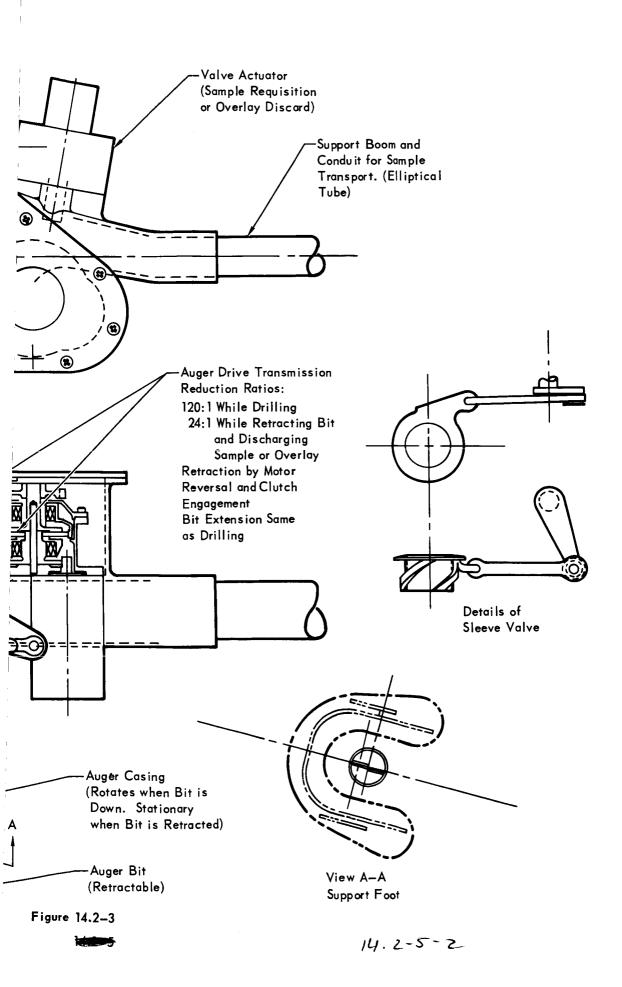to the desired depth the acquisition head is elevated and the sample material is

14.2-3

Figure 14.2-2

14.2-4

SAMPLE ACQUISITION HEAD CONFIGURATION

Support Foot Actuator

Support Foot Linkage

Clutch

Sample Catch Manifold

Overlay Material Discarded through Open Valve Here

A

14.2-57

Valve Actuator
(Sample Requisition
or Overlay Discard)

Support Boom and
Conduit for Sample
Transport. (Elliptical
Tube)

Auger Drive Transmission
Reduction Ratios:

120:1 While Drilling
 24:1 While Retracting Bit
      and Discharging
      Sample or Overlay
Retraction by Motor
Reversal and Clutch
Engagement
Bit Extension Same
as Drilling

Details of
Sleeve Valve

Auger Casing
(Rotates when Bit is
Down. Stationary
when Bit is Retracted)

A

Auger Bit
(Retractable)

View A–A
Support Foot

Figure 14.2–3

transported by gravity to the processing equipment conveyor. Programming then acti-
vates the boom length actuator for a one increment (3 inch) extension and the drill-
ing operation is repeated. Upon maximum extension of the boom, the boom is auto-
matically retracted and the azimuth actuator is activated for an incremental (3
degree) change in azimuth. Drilling and sample gathering continues until a sufficient
material batch is acquired for the processor. A discrete signal from the processor
terminates drilling operations for the experiment period.

Internal control will automatically terminate drilling in any single boring
if impenetratable material is encountered and the operations will proceed to the next
incremental boom position.
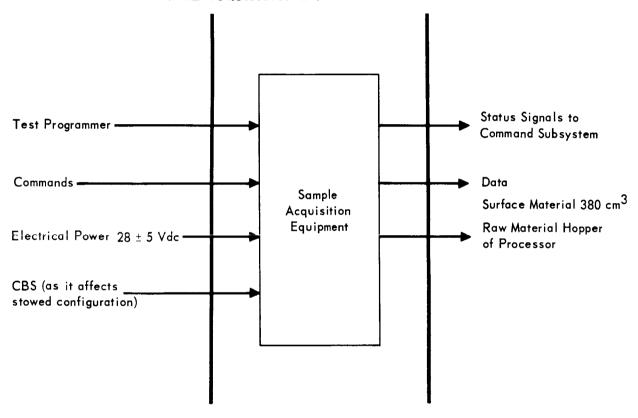
Sample acquisition will be accomplished at four intervals during the mission:

a. immediately after landing (1st hour)

b. in the morning (2nd hour)

c. in the evening (10th hour)

d. during the night (18th hour)

The surface sample acquisition equipment has an electrical power allocation
that permits accumulated drilling time of one hour. After acquiring sample material
from the far left and near left sectors of the reachable area 120° azimuth and 5 to 9 foot
reach) for the first two intervals (a and b above), the equipment will be programmed
to the near right sector for the third interval (c) and to the far right sector for the
fourth interval (d). Earth commands to the Sequencer Subsystem (Section 2.0) can
change the preprogrammed sequence described above to enable drilling and sample ac-
quisition from any point within the attainable surface area.

14.2.1.5 Performance Objectives - The performance objectives of the surface sample
acquisition equipment are as follows:

a. Collection of 380 cm^3 of sample material within a one hour period from a
   minimum of three sites.

b. Rejection of one centimeter or more of surface soil for elimination of
   contaminants and for sample acquisition at greater depths.

14.2.1.6 Interface Definition - The interfaces between the surface sample acquisi-
tion equipment and other equipment are shown in Figure 14.2-4 and 14.2-5.

14.2.1.7 Reliability and Safety Considerations - The soil sampler which provides
samples to the alpha spectrometer, the growth detector, the gas chromatograph and
the metabolism detector is not functionally backed up by any other unit. If the
sampler fails, data will not be obtained from the alpha spectrometer and growth de-
tector. The other instruments will, however, make partial measurements. The gas
chromatograph will analyze atmospheric and subsurface gases and the metabolism

14.2-6

SAMPLE ACQUISITION EQUIPMENT INTERFACE DIAGRAM

Test Programmer ⟶

Commands ⟶

Electrical Power 28 ± 5 Vdc ⟶

CBS (as it affects stowed configuration) ⟶

Sample Acquisition Equipment

⟶ Status Signals to Command Subsystem

⟶ Data

Surface Material 380 cm^3

⟶ Raw Material Hopper of Processor

Figure 14.2–4

14.2–7

SOIL ACQUISITION EQUIPMENT
ELECTRONIC INTERFACE SUMMARY

1. OPERATING MODES

MODE	MODE CHARACTERISTICS
Soil Sampling	Operations total 2 hours. Operations intermittent with sample processor. Operations interleaved. Total drilling time of one hour.

2. DATA CHARACTERISTICS

PARAMETER	FORM	ACCURACY	REMARKS	
Soil Sampler				
Azimuth	0–5V	7 bits	Sample one/minute	
Reach	0–5V	7 bits	Sample one/minute	
Voltages (2)	0–5V	7 bits	Sample one/second	During two hours of operation only
Currents (2)	0–40mV	7 bits	Sample one/second	
Direction	B.L.	1 bit	Sample once/two seconds	
Foot Position	0–5V	7 bits	Sample once/four seconds	

3. COMMAND AND SEQUENCING SUMMARY

COMMAND	TYPE	MAXIMUM NRT, DELAY & TOLERANCE	MAXIMUM PROPORTIONAL VALUE & TOLERANCE	MODE/ TIME OF OCCURRENCE
Sampler Power On	D–NRT–R&NR	1h ± 1m		
Sampler Power Off	D–RT–R&NR			Upon Sample Complete
Sample Azimuth	P–RT–R		120 Values	
Sample Reach	P–RT–R			
Foot Position	P–RT–R			

D   – Discrete
P   – Proportional
NRT – Non Real Time
RT – Real Time
R   – Radio
NR – Non Radio
BL – Bi-level

Figure 14.2–5

14.2–8

detector will make in situ measurements. Since many experiments depend on the sampler, a design for maximum reliability is essential.

The major safety consideration is protection from accidental actuation of the deployment mechanism or drill.

14.2.1.8 <u>Test Requirements</u> - Circuit continuity checks and simulated functional sequencing tests will be performed to verify proper operation of equipment after installation in the spacecraft.

14.2.1.9 <u>Development Requirements</u> - All elements of the surface sample acquisition equipment are of proven design and no long lead time item developments are required. Compatibility tests for total system operation with the soil sampler, processor and instruments will be necessary during the development of the sampler.

14.2.2 <u>Surface Sample Processing Equipment</u> - The purpose of the processing equipment is to take the raw material coming out of the sample acquisition device and process it to produce samples with the three particle size ranges required for the science instruments, 0 to 500 μ , 50 to 500 μ , and 0 to 200 μ . The processor receives up to 380 cm^3 of raw material, if needed, and provides 92 cm^3 of processed samples to the instruments. The total volume required is determined primarily by the alpha spectrometer.

14.2.2.1 <u>Equipment Identification and Usage</u> - The major elements of the processor, Figure 14.2-6, include two storage bins, three particle size separators, material transportation devices, sample quantity measuring device, system purge devices, processor control programmer, and a low pressure gas supply. The processor block diagram, Figure 14.2-7, illustrates the sequence in which these elements are used.

<u>Storage Bins</u> - The storage bins are used to retain surface sample material until a desired quantity has been accumulated and until the material is required. The first storage bin has a capacity of 40 cm^3 and is used as a hopper. The second bin is used as a weighing bin for surface sample particles which have passed through the 500 micron screen. The weighing bin is spring mounted and calibrated such that the difference in the force required to move the bin to a specified location along its vertical axis, before and after filling, will indicate the weight of the contents. The method of moving the bin along its vertical axis is through a solenoid type mechanism. Both bins have full-bin indicators activated by the blockage of light from one side of the bin to the other by the build up of material. The weighing bin has a second light blockage indicator to detect the presence of a minimum amount of material.

o <u>Particle Size Separators</u> - The particle size discrimination and separation devices process surface samples such that particles below a certain size
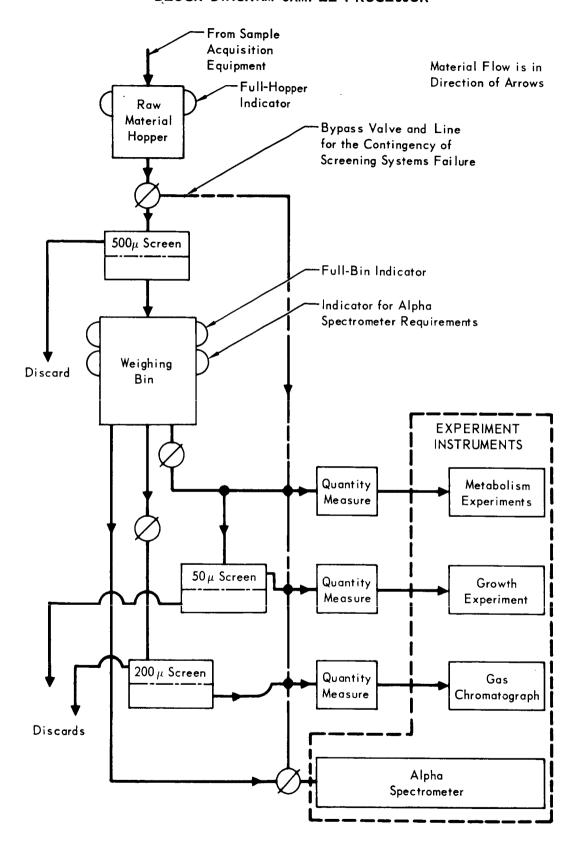
BLOCK DIAGRAM SAMPLE PROCESSOR

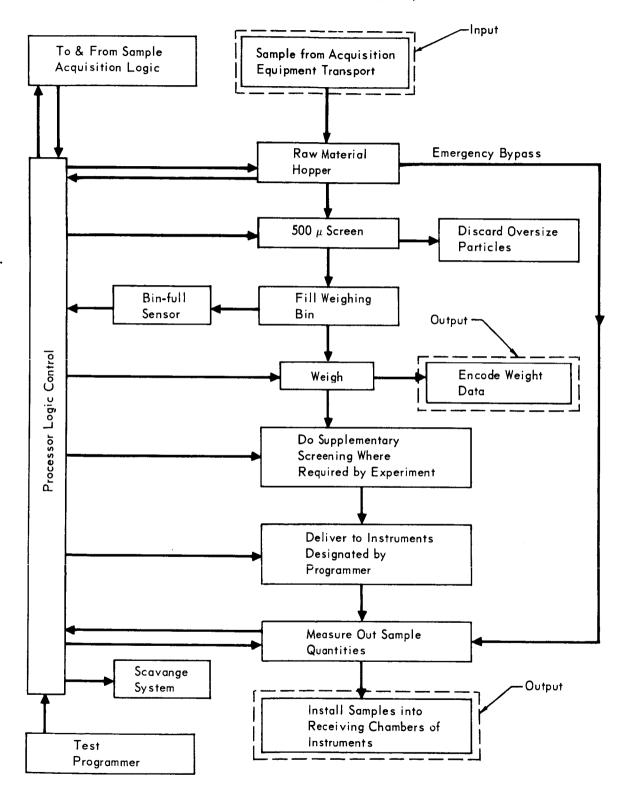Figure 14.2–6

SAMPLE PROCESSOR
(FUNCTIONAL BLOCK DIAGRAM)

Figure 14.2-7

are passed while particles above that size are rejected. One device is provided to pass particles of less than 500 microns in largest dimension, one device to pass particles of less than 200 microns, and one device to pass particles of less than 50 microns. The 500 micron device consists of a rotating drum filter screen. The particles under 500 microns pass through the cylindrical screen while the larger particles continue through the center of the drum and are discarded. The 50 micron device utilizes low pressure gas to provide a pneumatically activated swirl such that the larger and heavier particles are passed to the outer periphery of the device while the lighter particles and gas depart through a central opening. Separation is based on the ratio of aerodynamic drag to particle mass. The 200 micron devices will be similar to the 500 micron devices.

o   Material Transportation Devices - Three methods of transporting materials are utilized:

a.   A belt and cup conveyor is used at the interfaces between the surface sampling unit and the processor.

b.   The material is transported through tubes by means of short bursts of pressurized gas when particle sizes and quantities are small.

c.   The remainder of the transport is by gravity in drop chutes.

o   Sample Quantity Measuring Device - The sample quantity measuring devices for the experiments consist of sample cups of the desired volume and a scraper. The cup is over filled and the scraper removes the excess, leaving only the desired quantity.

o   System Purge Devices - A system of ports and gas lines is provided. When the ports are opened, the system is purged of all residual materials by a pressurized gas flow.

o   Control Programmer - The control programmer controls the sample processor with the proper timing and in the correct sequences. The control programmer utilizes solid state electronic devices.

o   Low Pressure Gas Supply - A gas supply is provided for pneumatic sample transportation and for the gas purge.

14.2.2.2   Design Requirements and Constraints - The surface sample processing equipment design, construction, and operation will satisfy the constraints and

requirements of the "1973 VOYAGER Capsule Systems Constraints and Requirements Document," dated January 1, 1967 and May 18, 1967. The surface sample processing subsystem will operate from a power source voltage range of 23 vdc to 33 vdc. Maximum power requirements will not exceed 45 watts. Average power will not exceed 10 watts for a total of 40 minutes maximum operation time. As much as 380 cm^3 will have to be processed and the required output is 92 cm^3 of samples graded into three size ranges.

14.2.2.3 <u>Physical Characteristics</u> - The subsystem weight is 8.0 lbs. Total volume is 420 cubic inches. The overall configuration is rectangular with dimensions of 6" x 7" x 10".

14.2.2.4 <u>Operation Description</u> - Upon receipt of a surface sample from the Sample Acquisition Subsystem (see 14.2.1), the processing equipment conveys the sample to the raw material hopper. This operation is continued until the subsystems are deactivated externally or until the processing unit provides a signal to the sample acquisition unit indicating that either the weighing bin or the raw material hopper is full. The sample material passes through the raw material hopper, through the 500 micron screening process, through the weighing bin, and is delivered to the metabolism and growth experiments. That material which goes to the growth experiment receives an additional screening to filter out particles below 50 microns in size which are discarded. The proper sample quantities are then delivered to the experiments. Following delivery of material to the metabolism and growth experiments, the exit port on the weighing bin is closed and the bin is allowed to fill. At this time the contents of the bin are weighed and the results supplied to the telemetry subsystem. Following weighing, sample material is passed through the 200 micron filter for the gas chromatograph until the desired quantity is obtained, then the sample is delivered to the gas chromatograph. At this time, unless the weighing bin lower quantity indicator indicates inadequate sample bulk, the remaining bin contents is spread evenly onto the sampling pan of the alpha spectrometer. In the event of screening failures, indicator malfunction, or disproportionately large particle size, material is transferred from the raw material bin directly to the experiment sample measuring devices, thereby bypassing all screening and the weighing bin. In this situation, the needs of the metabolism, growth, and gas charomatograph experiments are supplied first and the remaining material is supplied to the alpha spectrometer. After all operations have been performed with a given sample, the sample processing equipment is gas purged of all remaining trapped or unused sample material in

preparation for taking another sample. A total of four complete soil processing operations are completed within 40 minutes accumulated operating time. It should be noted that although only four complete soil processing operations are done, the number of samples and sample size to a given experiment is variable depending on the programming and on the number of different sample quantity measuring devices provided.

14.2.2.5 **Performance Objectives** - The basic performance objectives are the delivery of soil samples of proper particle size and quantity to the desired experiment, as summarized in Figure 14.2-8 and 14.2-9.

14.2.2.6 **Interface Definition** - Interfaces of the subsystem with other subsystems is shown diagrammatically in Figure 14.2-10. The electronic interfaces are described in detail in Figure 14.2-11.

Raw Surface Material - Surface sample material (particle size up to 1.5 mm in diameter) will be provided in quantities as required by the processor (380 cm³ maximum).

14.2.2.7 **Reliability and Safety Considerations** - For operational reliability:

   a. Actuators must function when called upon.

   b. Status indicators (including full-bin indicators) must report status correctly, and program commands must be activated.

   c. The three screening systems must not clog or choke up.

   d. The raw sample delivered to the processor must contain a sufficient percentage of desired particle sizes to meet experiment sample needs without unproductive expenditure of time.

Of these, the actuators attain reliability by use of rugged proven designs, by protection of transmissions against dust damage and by use of space qualified dry film lubrication at all rubbing surfaces. Status indicators are primarily for programmer control and for malfunction analysis. Indication of fullness is merely the blockage of light to a photo cell by the pile up of sample material in the upper, narrowed section of the bin.

The separation and discrimination functions of the 500μ and 200μ screens may be more effectively performed, if necessary, by using tumbling weights as agitators to prevent caking and clogging. The 50μ pneumatic swirl is designed to respond to purging, if for any reason, it becomes choked with materials. A development testing program is needed to determine the most practical and reliable design.

SCIENCE EXPERIMENT PROCESSED SAMPLE REQUIREMENTS

SCIENCE EXPERIMENT	PARTICLE SIZE RANGE (DIAM.)	SAMPLE QUANTITY PER EXPERIMENT cm^3	NUMBER OF SAMPLES REQUIRED	MINIMUM TOTAL SAMPLE cm^3	REQUIRED SAMPLE WITH RESIDUAL & SPILLAGE ALLOWANCE cm^3
α-Scattering Spectrometer	Below 500μ	24	3	72	72
Metabolism	Below 500μ	0.15	60	9	15
Growth	50μ to 500μ	0.015	5	0.1	1
Gas Chromatograph	Below 200μ	0.15	4	0.6	4
Total					92
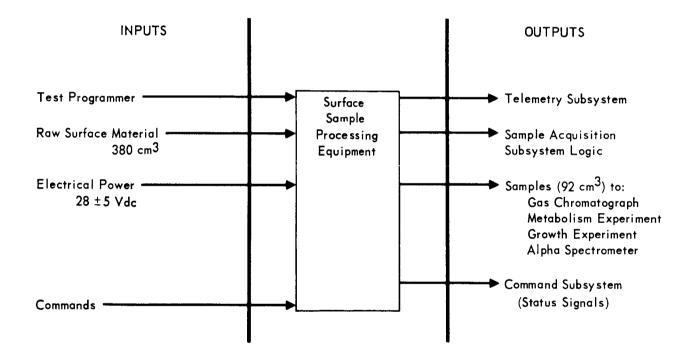
Figure 14.2-8

BATCH PROCESSING REQUIREMENTS

SCIENCE EXPERIMENT AND PARTICLE SIZES REQUIRED	SAMPLE BATCHES			
	No. 1 (1st hr.) (cm^3)	No. 2 (2nd hr.) (cm^3)	No. 3 (10th hr.) (cm^3)	No. 4 (18th hr.) (cm^3)
Metabolism 　Below 500μ	15	–	–	–
Growth 　50μ to 500μ	1	–	–	–
Gas Chromatograph 　Below 200μ	1	1	1	1
Alpha-Spectrometer 　Below 500μ	–	24	24	24
Total of Processed Samples (cm^3)	17	25	25	25

Figure 14.2-9

14.2-15

SURFACE SAMPLE PROCESSING EQUIPMENT INTERFACE DIAGRAM

INPUTS		OUTPUTS

Test Programmer ————————▶ **Surface Sample Processing Equipment** ————▶ Telemetry Subsystem

Raw Surface Material ————▶ ————▶ Sample Acquisition Subsystem Logic
380 cm^3

Electrical Power ————▶ ————▶ Samples (92 cm^3) to:
28 ±5 Vdc 　　　　　　Gas Chromatograph
　　　　　　Metabolism Experiment
　　　　　　Growth Experiment
　　　　　　Alpha Spectrometer

Commands ————————▶ ————▶ Command Subsystem
　　　　　　(Status Signals)

Figure 14.2–10

14.2–16

ELECTRONIC INTERFACE SUMMARY

DATA:

PARAMETER	FORM	ACCURACY	SAMPLE RATE	REMARKS
Gas Supply Pressure	0–40mV	7 bits	One/Hour	
Density (Weight)	0–5V	7 bits	3 Samples Total, on Command	
Purge Status	B.L.	1 bit	Sample One/Minute	
Bin Ready (3)	B.L.	1 bit	Sample One/Minute	

STATUS SIGNALS	FUNCTION
Processing Complete	To Sequencer
Density Measurement Ready	Data System Alert
Spectrum Samples Ready	For Sequencing
G.C. Samples Ready	For Sequencing
Growth Samples Ready	For Sequencing
Metabolism Samples Ready	For Sequencing

POWER:

AVERAGE	VOLTAGE	PEAK	DURATION
10W	29 ± 6Vdc	45W	40 Minutes

COMMAND AND SEQUENCING SUMMARY

COMMAND	TYPE	MAXIMUM NRT, DELAY & TOLERANCE	MAXIMUM PROPORTIONAL VALUE & TOLERANCE	MODE/TIME OF OCCURRENCE
Processing Power On	D–NRT–R&NR	1h ± 1m		
Processing Power Off	D–RT–R&NR			Upon Process Complete
Density Read	D–RT–NR			Upon Density Measurement Ready
Clock	D–RT–NR			
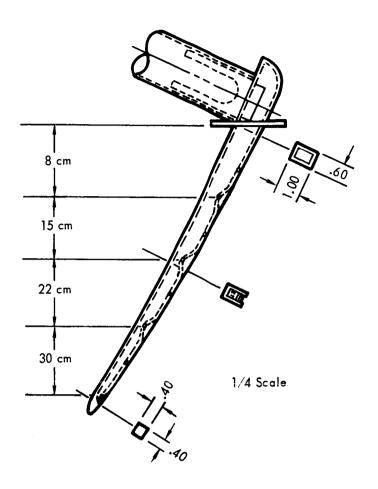
D — Discrete
P — Proportional
NRT — Non Real Time
RT — Real Time
R — Radio
NR — Non Radio
BL — Bilevel

In the event the particle size population is disproportionately distributed toward the larger diameters, or if any of the indicators have malfunctioned, a command override can open the valve immediately below the raw material hopper to a bypass line, which then feeds unprocessed materials directly to the quantity measuring devices of the metabolism, growth and gas chromatograph instruments. After allowing time for their requirements to be fulfilled, another valve is opened and the sample requirements for the alpha spectrometer will be supplied. This same alternate path can serve for emergency operation in the event of failure of one or more of the screening systems.

14.2.2.8 **Test Requirements** - Type approval and flight approval qualification tests will be conducted on the sample processor before mounting it on the surface laboratory. After mounting, testing will primarily consist of circuit continuity checks, functional sequencing, and gas pressure measurements to verify operational compatibility with the surface laboratory and other components.

14.2.2.9 **Development Requirements** - There is very little precedent for an automatically operated system similar to the sample processor although its individual components do not involve unique operations. Therefore, after establishing preliminary proportions, the actual design must begin as a breadboard model and be tested with a representative variety of simulated Mars soil samples. Choking of lines, poor outflow of material from bins, clogging of screening systems and grit-jamming of valves or of quantity measuring devices are examples of potential problems requiring further consideration.

14.2.3 **Subsurface Probe Mechanism** - The purpose of the subsurface probe is to make measurements of the soil temperatures below the surface and to obtain samples of gases trapped beneath the surface for analysis by the gas chromatograph. This section describes the entire probe except for the temperature instrumentation which is discussed in Section 14.3.10.

14.2.3.1 **Equipment Identification and Usage** - The subsurface probe mechanism, Figure 14.2-12, consists of the probe structure, probe deployment mechanism, gas sampling vents and tubes, and gas pump. The subsurface probe temperature sensors defined in Section 14.3.10 are mounted within the hollow probe. The probe mechanism is used to implant the gas sample acquisition ports and temperature sensors below the soil surface after the Surface Laboratory has landed.

    o <u>Boom</u> - The boom is an elliptical tube shaped to clear the Capsule Bus Lander for a soil surface penetration 30 inches below the plane of the lower surface of the laboratory and for positioning the probe at a radius of 60 inches from the boom pivot on the laboratory. Boom stiffness keeps

8 cm

15 cm

22 cm

30 cm

.60

1.00

.40

.40

1/4 Scale

Stowed

Beam and Belt Drum
of Actuator Mechanism

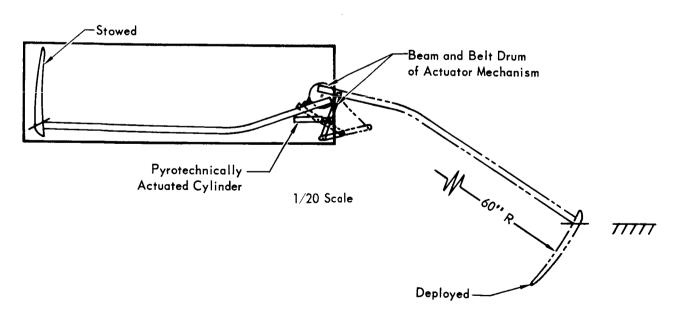Pyrotechnically
Actuated Cylinder

1/20 Scale

60" R

Deployed

Figure 14.2-12

14.2-19

deflection during probe penetration small and minimizes the tendency to elongate the hole about the probe. Gas tubing and wiring associated with the sensors pass through the boom.

o Probe - The probe is a convex-contoured structure with provisions for four gas sampling ports plus the internal installation of associated gas tubing, and nine temperature sensors with their wiring. The external surface of the probe is recessed at each gas port to provide protection for the port during surface penetration.

o Actuating Mechanism - The actuating mechanism consists of a clamp for stowing the probe and a pyrotechnic actuator and linkage unit for deploying and imparting energy to the probe for soil penetration. Both the clamp and actuator are pyrotechnically actuated in simultaneous operation. The actuator and linkage provide approximately uniform torque to the probe and deliver over 1000 pound-inches of kinetic energy, resulting in a nominal impact velocity of 55 ft/sec.

o Gas Sampling Ports and Lines - The gas intake port is an 0.15 inch diameter opening in a protected recess of the probe and the entrance of dust is restricted by a 60-mesh screen. The tube for conducting the gas sample to the pump is 0.060 inch I.D. and is carried within the boom.

o Gas Sampling Pump - This expansion pump, mounted inside the Surface Laboratory, draws in subsurface gas samples through the probe and transfer those samples to the gas chromatograph for analysis. Displacement per stroke is 16 cm^3. The pump is operated by spring action during intake and by external gas pressure during discharge.

14.2.3.2 Design Requirements and Constraints - Deployment of the probe into the soil is accomplished with minimum disturbance to the original surface conditions. The probe will provide effective contact with the surrounding soil throughout its length. Location of the probe will be beyond the shadows cast by the Capsule Bus Lander during at least 50 percent of the daylight period.

14.2.3.3 Physical Characteristics - The configuration of the subsurface probe mechanism is shown in Figure 14.2-12. The maximum weight of the probe mechanism, including the temperature transucers and associated gas lines and pump, is 6.0 lbs. The pump is 4" x 5" x 6". The physical characteristics are listed in Figure 14.2-13.

14.2.3.4 Operation Description - The subsurface probe mechanism operates within 16 to 18 minutes after landing of the Surface Laboratory. The electro-explosive device (EED) control module (Section 6.0) provides ignition power to the pyrotechnic

TABLE OF CHARACTERISTICS

SUBSURFACE PROBE MECHANISM

Penetration Depth: 30 cm

Deployment Swing Radius: 5 feet

Pump
  Size: 4 In. x 5 in. x 6 in.
  Location: Equipment Section
  Purpose: Draws in subsurface gas through the probe vents and transfers the gas to the gas chromatograph

Weight (Including gas sampling ports, tubes and pump,
    also temperature sensors and lines.)   6.0 lb

clamp and deployment actuator which drives the probe through at least 200 degrees rotation from the stowed position into the surface.

The gas sampling pump is activated when the gas chromatograph operating cycle requires a subsurface gas sample for analysis. The pump vacuum draws the subsurface gas and transfers the sample to the gas chromatograph. Subsurface gas sample analysis is scheduled:

    a. once during the day

    b. three times near sunset

    c. once during the night

    d. three times near sunrise

14.2.3.5 <u>Performance Characteristics</u> - The probe achieves an impact velocity of 55 ft/sec. This energy is sufficient to embed the probe to its full depth (30 cm) in cohesionless sand with a 50 percent margin to accomodate a small admixture of rubble.

14.2.3.6 <u>Interface Definition</u> - The subsurface probe mechanism provides for installation of the gas sampling and temperature sensors and deploys the sensors at a range of depths below the soil surface. The Surface Laboratory structure subsystem provides support and load points for mounting the mechanism. Clearance of the probe sweep envelope is provided during deployment. Electrical impulse to accuate the pyrotechnic device is provided by the control module, Figure 14.2-14.

14.2.3.7 <u>Reliability and Safety Considerations</u> - All pyrotechnics meet the 1 amp - 1 watt no-fire requirements. The deployment mechanism, which uses an enclosed pyrotechnic cylinder, is designed so that it will not explode even if the piston is prevented from moving when the pyrotechnic is discharged.

There are no functionally redundant measurements for the subsurface temperature measurements and subsurface gas sample analysis which will provide data if the probe fails. The spectral measurements and vehicle temperatures will however, permit an evaluation of the surface temperature in the absence of probe data.

14.2.3.8 <u>Test Requirements</u> - No operation preflight or in-flight tests are required for the mechanism other than simple transducer voltage and continuity measurements.

14.2.3.9 <u>Development Requirements</u> - The probe mechanism is of proven design and no long lead item developments are required. Development will be directed toward meeting the objectives of obtaining surface penetration in a manner such that the temperature sensors will be in close contact with the soil and the gas sampling ports will ingest subsurface gas rather than surface atmospheric gases which leak down along the sides of the probe.
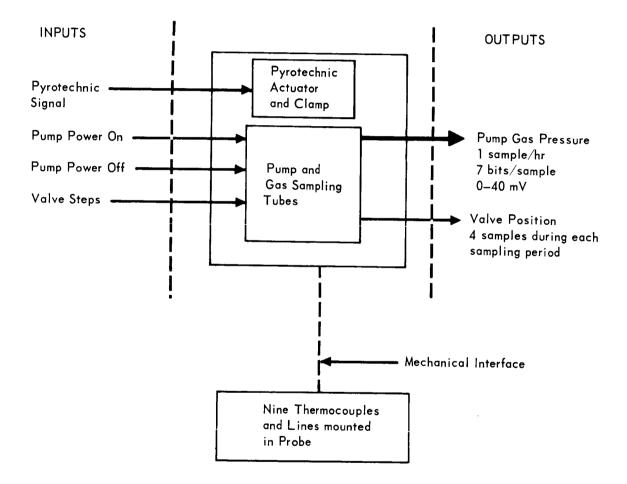
INTERFACE DIAGRAM SUBSURFACE PROBE MECHANISM

INPUTS

OUTPUTS

Pyrotechnic
Signal

Pump Power On

Pump Power Off

Valve Steps

Pyrotechnic
Actuator
and Clamp

Pump and
Gas Sampling
Tubes

Pump Gas Pressure
1 sample/hr
7 bits/sample
0–40 mV

Valve Position
4 samples during each
sampling period

Mechanical Interface

Nine Thermocouples
and Lines mounted
in Probe

Figure 14.2–14

14.2–23

14.3 SCIENCE INSTRUMENTS - The functions of the science instruments which make measurements and observations required for scientific experiments on the surface are listed in Figure 14-1. Definitive functional descriptions of each scientific instrument appear in subsections 14.3.1 through 14.3.10.

14.3.1 <u>Facsimile Camera</u> - The function of the Facsimile Camera is to perform all imaging on the Mars surface including a 90° x 360 stereoscopic panoramic survey of the terrain surrounding the landing site and five 24°x24° high resolution frames of the soil sampling and experiment areas. The resolution for the panoramic survey is 0.3° while the five individual frames have a resolution of 0.06° which is necessary for observation of fine detail in the surface sampling areas.

14.3.1.1 <u>Equipment Identification and Usage</u> - The equipment consists of two facsimile cameras (FAC) mounted on opposite sides of the SLS, each having the capability to operate at a resolution of either 0.3° or 0.06°. The physical arrangement of a camera is shown in Figure 14.3.1-1. To obtain the stereo panoramic survey, both cameras are operated for a full 360° at 0.3° resolution. Stereo reproduction of features will depend upon the relative location with respect to the cameras. Features on a line connecting the two cameras yield no stereo information and features at right angles to this line yield maximum stereo information.

The five 24°x24° images of the experimental and surface sampling sites will be obtained by commanding the respective camera to the correct azimuth and elevation angles using the on-board programming system. If areas of special interest appear in the panoramic scan, they can be viewed at higher resolution by reprogramming one of the five 24°x24° high resolution frames by means of an Earth override command.

The major components of this camera are a fixed focus optical assembly, an electromechnical scanning assembly, scan motor drive electronics, a photo-electric transducer, an amplifier, and for purposes of correlation, a synchronously driven in light chopper. A schematic block diagram of the camera in Figure 14.3.1-2 shows the relationship of these major components.

Optical Assembly - The optical assembly consists of an objective lens which focuses the radiation through a pinhole onto a photosensitive surface. The size of the pinhole and the focal length determine the instantaneous field of view which determines the resolution of the camera. A three inch focal length with a 12.5×10^3 inch pinhole and a six inch focal length with a 5×10^{-3} inch pinhole provide resolutions of 0.3° and 0.06°, respectively.

VOYAGER IMAGING FACSIMILE CAMERA

Cover Actuator
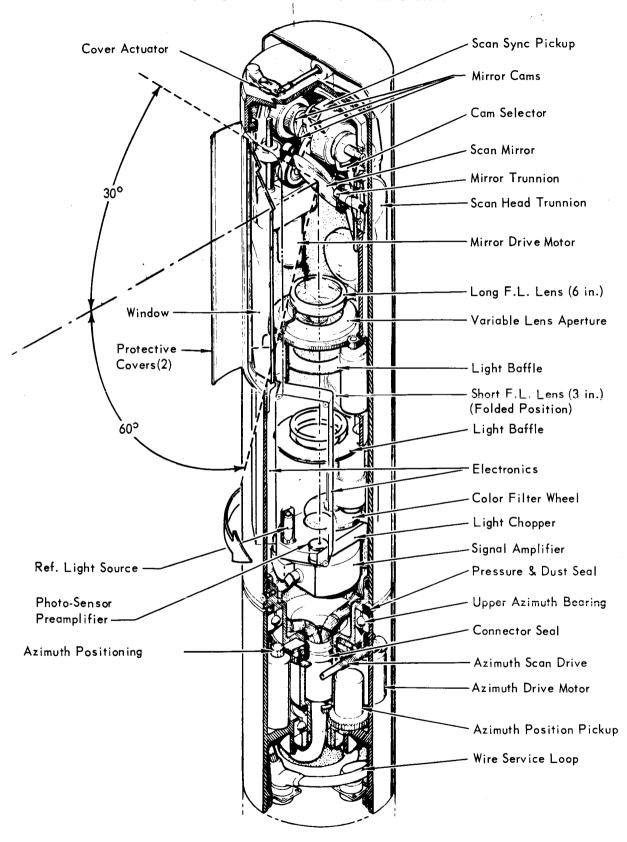
30°

Window

Protective Covers(2)

60°

Ref. Light Source

Photo-Sensor Preamplifier

Azimuth Positioning

Scan Sync Pickup

Mirror Cams

Cam Selector

Scan Mirror

Mirror Trunnion

Scan Head Trunnion

Mirror Drive Motor

Long F.L. Lens (6 in.)

Variable Lens Aperture

Light Baffle

Short F.L. Lens (3 in.) (Folded Position)

Light Baffle

Electronics

Color Filter Wheel

Light Chopper

Signal Amplifier

Pressure & Dust Seal

Upper Azimuth Bearing

Connector Seal

Azimuth Scan Drive

Azimuth Drive Motor

Azimuth Position Pickup

Wire Service Loop

Figure 14.3.1-1

14.3-3

FACSIMILE CAMERA FUNCTIONAL BLOCK DIAGRAM

The lens diameter of 1 inch and the 6 inch focal length provides an F/6 system for the high resolution images. For this high resolution system 0.06° at F/6, all points from 20 feet to infinity are in focus for one camera. The other facsimile camera near the sampler will be focused for high resolution views of the sampling area but not objects far away. For the lower resolution system, 0.3° at F/3, the depth of field extends from 4 feet to infinity. Thus, a satisfactory depth of field range for both cameras is available.

Scanning Mechanism - Elevation and azimuth scanning is performed mechanically in the facsimile camera. The high rate elevation sampling is accomplished using an oscillating mirror, shown in Figure 14.3.1-1, with the elevation angle range controlled by a cam on the mirror drive. Every 0.2 second, one line of the scene, one resolution element wide, is scanned. Simultaneously, and in synchronism, the entire mirror assembly is rotated in azimuth so that the next mirror scan will see an adjacent line displaced by one resolution element. Both the elevation and azimuth scan rates are derived from hysterisis type A.C. motors which are synchronized using a common frequency standard.

Transducer - The beam of light from the scanning mechanism is focused through a pinhole onto a silicon detector which has a spectral sensitivity from 0.5 to 1.1 microns and a time constant of several microseconds. The operating temperature of this detector must be calibrated and controlled since it functions similar to a temperature sensitive resistor. A Peltier cooler is used to stabilize the detector temperature slightly below that of the coolest internal operating temperature to guarantee a known operating condition.

14.3.1.2 Design Requirements and Constraints - The design requirements and constraints are:

    o The cameras must be mounted so that a relatively unobstructed view of the features to be imaged is obtained.

    o Camera operation must be performed during a period of no SLS motion caused by disturbances such as experiment deployment.

    o The data system must accept data from each facsimile camera at a rate of 12,000 bits/second while recording 24° x 24° images and 9,000 bits/second during panoramic scanning.

    o The dynamic range of the camera must be large enough to operate in light levels existing with or without cloud cover, albedo values between 0.05 and 0.35, and lighting levels corresponding to landing at latitudes

from 10°N to 40°S.

o The field of view coverage for the panoramic survey should include imaging of the sampling area, subsurface probe area, and the in situ metabolism instruments.

o Thermally, the cameras must be designed to be as completely self-sufficient as possible since they protrude above the SLS envelope.

14.3.1.3 Physical Characteristics - The two cameras are mounted on the SLS as shown in Figure 14.3.1-3. Size, weight and power requirements are shown in Figure 14.3.1-4.

To solve the problem of thermal control, the external camera structure is formed of both radiatively reflective and insulative material to create as close to an adiabatic chamber as possible. Low environmental temperatures are expected to be the most troublesome, thus an internal heater is employed to regulate the compartment temperature during the brief periods of imaging. Demands on the environmental control system are small since the camera operation is programmed to occur under favorable conditions. The camera is warmed up for 15 minutes before imaging operation using 7.5 watt heaters.

14.3.1.4 Operation Description - The operation of the camera will be programmed to occur when experiment deployment is not scheduled as shown in Figure 14.3.1-5. Operation is not dependent upon wind conditions because the cameras are rigidly mounted to the SLS.

Operation will be commenced after all experiments are deployed and when the sun angle is between 30° to 60°, mid-morning or late afternoon, so adequate contrasts due to shadows exist. A 90° x 360° panorama requiring 240 seconds will be secured initially with input to the data storage at the rate of 9,000 bits/second for a total storage of 2.16×10^6 bits during the 240 second period. Following the first panoramic scan, a second panorama will be made with the other camera to obtain the stero information. Time sequencing of this operation is shown in Figure 14.3.1-6. With the approximate 4 foot baseline between the two cameras, stereo ranging error will be ±13 feet at a range of 100 feet for the 0.30° resolution panoramic scan.

In the afternoon of that same day, after the panoramic imaging is completed, the cameras are sequentially pointed at the sampling and experiment areas. Images of 24° x 24° coverage with a 0.06° resolution are obtained. Data output to the temporary storage is at the rate of 12,000 bits/second with a total storage per image of 0.96×10^6 bits. The total data output for the two
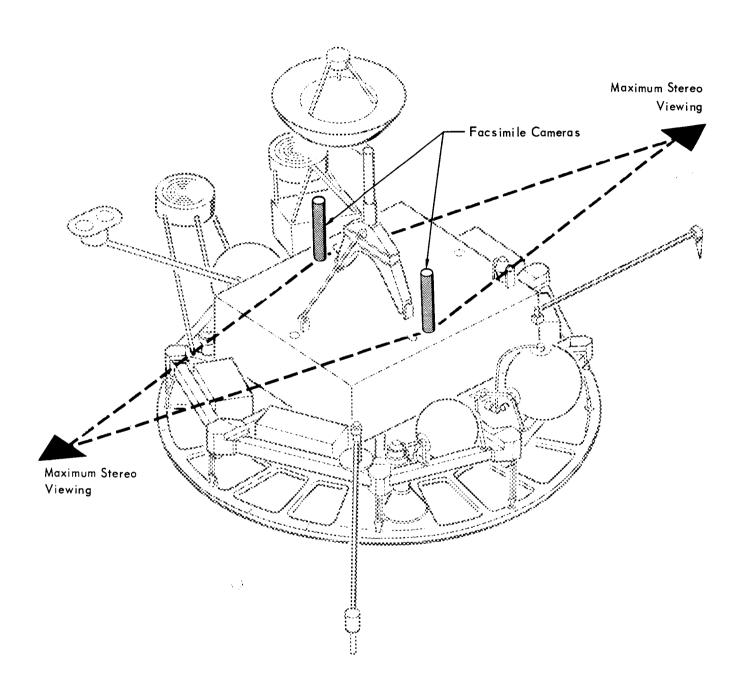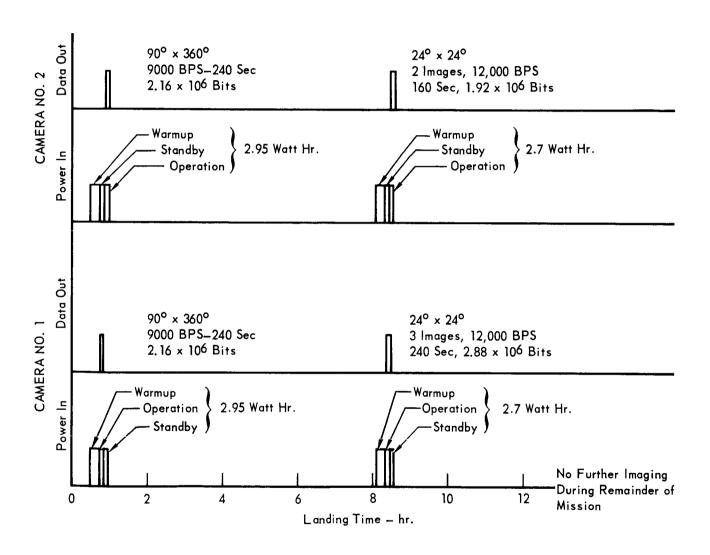
14.3-6

FACSIMILE CAMERA SYSTEM SLS LOCATION

Figure 14.3.1-3

14.3-7

PHYSICAL CHARACTERISTICS AND POWER REQUIREMENTS (TYPICAL)

COMPONENT	WEIGHT	VOLUME	POWER
Camera No. 1	6 lb	125 in.^{3}	6 watt
Camera No. 2	6	125	6
Electronics	3	120	3
Total	15 lb	370 in.^{3}	15 watt

SURFACE IMAGING CAMERA TIME SEQUENCE

Figure 14.3.1-5

14.3-9

TIME SEQUENCE PROFILE PANORAMIC IMAGING CAMERA

Figure 14.3.1—6

14.3—10
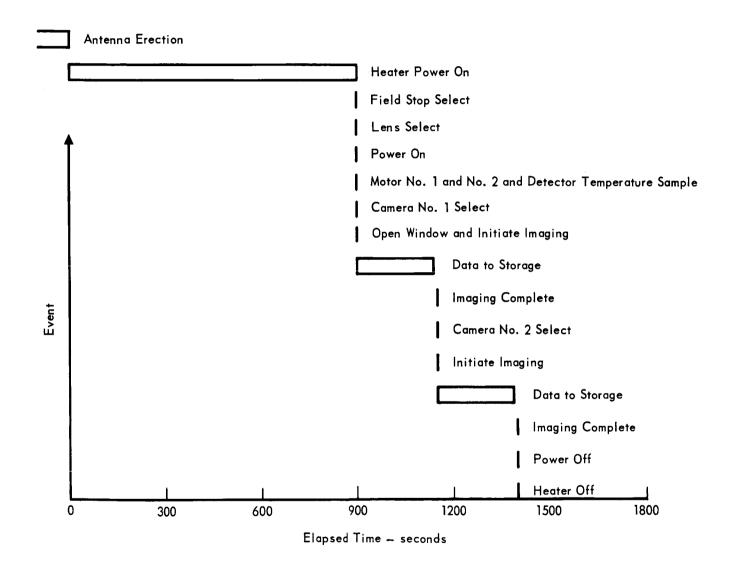
panoramic and five experiment site scans is 9.12×10^6 bits.

The camera produces a picture by systematically scanning the surroundings in a pattern similar to that of a television scan. A telescope having a very narrow field of view scans the scene in a series of closely spaced lines. The brightness data from each minute element of the scene is converted into an electrical signal for transmission to Earth. By performing this process in reverse with playback equipment at the Earth receiving station, an accurate reproduction of the scene is produced.

A time sequence profile of the camera internal operation during a 360° pan is shown in Figure 14.3.1-7. The profile shows that elevation position changes quite rapidly, 1200 cycles for every cycle of azimuth scan. The azimuth scan is a smooth continuous drive. At the end and beginning of each elevation scan, a synchronization pulse from a reference light source is added to the optical signal. The synchronization pulse is used to synchronize playback equipment.
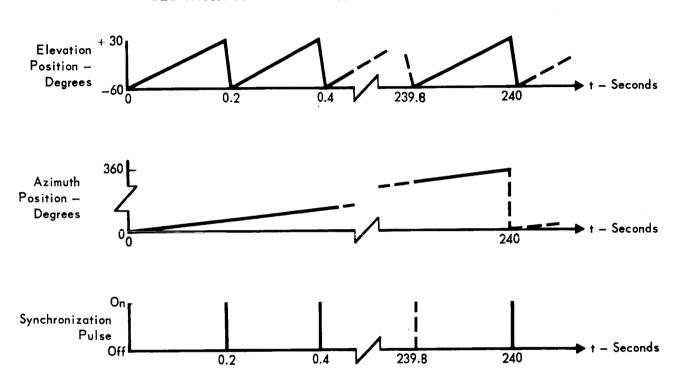
The camera operates at a fixed size aperture regardless of the surface lighting conditions because the photo detector has an adequate 100,000:1 dynamic range. This compares to 100:1 for vidicons which require aperture size control as a function of lighting conditions.

Resolution change from 0.3° to 0.06° is performed by a change of the effective focal length and field stop of the camera.

Camera instrumentation includes field stop position, both lens positions, motor and compartment temperatures, detector temperature, and azimuth position resolved to every 3°.

14.3.1.5 Performance Objectives - The prime performance objectives are:

o Two $360^\circ \times 90^\circ$ panoramas at 0.3° gross resolution to provide sterescopic pictures.

o Five $24^\circ \times 24^\circ$ frames of the sample gatherer, subsurface probe, and in situ biology experiment sites, at a resolution of 0.06°.

14.3.1.6 Interface Definition - The 12,000 bit/second data rate output is one of the most important interface characteristics of the facsimile cameras. Figure 14.3.1-8 identifies all functions interfacing with the cameras.

14.3.1.7 Reliability and Safety - Figure 14.3.1-9 shows the probability of obtaining a monoscopic and stereoscopic survey and imaging of the experiment sites. The single monoscopic survey has a high probability of being successfully obtained because redundant camera systems are used to provide separate surveys for the

CAMERA OPERATION TIME PROFILE
FOR A 360° PANORAMIC PICTURE WITH +30° TO -60°
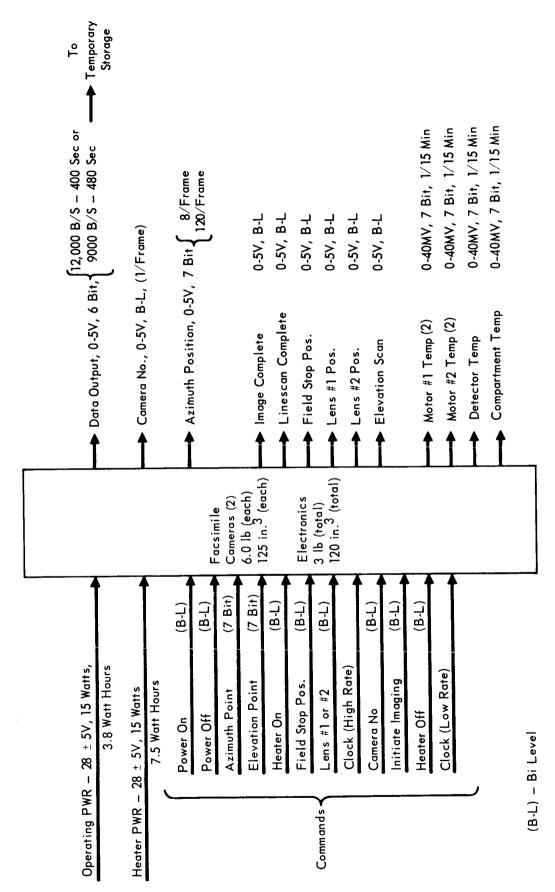### ELEVATION COVERAGE AND 0.3° ANGULAR RESOLUTION

FACSIMILE CAMERA INTERFACE DIAGRAM

To Temporary Storage

Data Output, 0-5V, 6 Bit, { 12,000 B/S – 400 Sec or / 9000 B/S – 480 Sec

Camera No., 0-5V, B-L, (1/Frame)

Azimuth Position, 0-5V, 7 Bit { 8/Frame / 120/Frame

Image Complete — 0-5V, B-L

Linescan Complete — 0-5V, B-L

Field Stop Pos. — 0-5V, B-L

Lens #1 Pos. — 0-5V, B-L

Lens #2 Pos. — 0-5V, B-L

Elevation Scan — 0-5V, B-L

Motor #1 Temp (2) — 0-40MV, 7 Bit, 1/15 Min

Motor #2 Temp (2) — 0-40MV, 7 Bit, 1/15 Min

Detector Temp — 0-40MV, 7 Bit, 1/15 Min

Compartment Temp — 0-40MV, 7 Bit, 1/15 Min

Operating PWR – 28 ± 5V, 15 Watts, 3.8 Watt Hours

Heater PWR – 28 ± 5V, 15 Watts, 7.5 Watt Hours

Facsimile Cameras (2)
6.0 lb (each)
125 in.³ (each)

Electronics
3 lb (total)
120 in.³ (total)

Commands:
Power On (B-L)
Power Off (B-L)
Azimuth Point (7 Bit)
Elevation Point (7 Bit)
Heater On (B-L)
Field Stop Pos. (B-L)
Lens #1 or #2 (B-L)
Clock (High Rate) (B-L)
Camera No (B-L)
Initiate Imaging (B-L)
Heater Off (B-L)
Clock (Low Rate) (B-L)

(B-L) – Bi Level

Figure 14..3.1–8

14.3–13

IMAGING SUCCESS PROBABILITY

IMAGE	PROBABILITY OF SUCCESS
Panoramic Survey	0.9936
Stereo Panoramic Survey	0.8464
24° x 24° Sites	0.9936

Figure 14.3.1-9

stereoscopic images.

14.3.1.8 <u>Test Requirements</u> - To assure that the data generated by the camera represents the scene and that camera operates correctly, a number of tests are made prior to the commencement of picture taking. Before installation, the camera is electro-optically tested and calibrated. Any nonlinearities are noted so that compensation can be provided during the playback phase. Focus and internal alignment adjustments are also made before installation. Tests verifying proper mechanical and electrical mating are made after installation in the SLS by briefly operating the equipment.

Prior to descent to Mars and while still attached to the Orbiter vehicle, an operational test will be made. A projected test pattern will be used to form a reference image. This image will be transmitted on a high data rate RF link to Earth for evaluation. After landing only those tests which show that the camera is operational will be made.
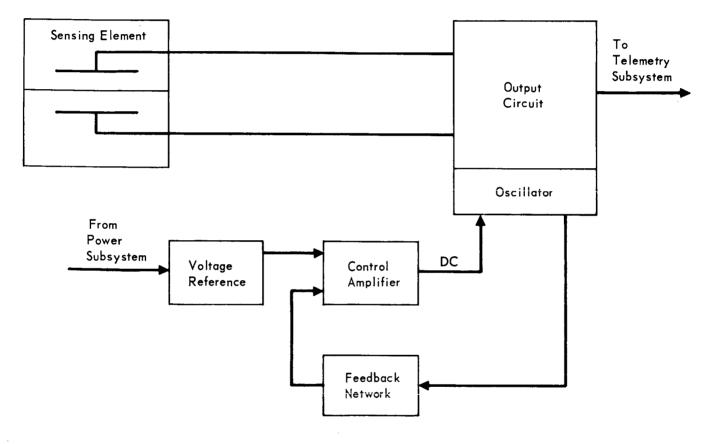
14.3.1.9 <u>Development Requirements</u> - A large amount of analytic and hardware development work has been performed on a facsimile camera suitable for a lunar landing and a preliminary design has been formulated for VOYAGER. The development of a camera suitable for use in the Mars environment is not expected to present any serious problems if given the proper emphasis.

14.3.2 <u>Atmospheric Pressure Transducer</u> - This instrument obtains periodic measurements of atmospheric pressure on Mars during the entire surface mission.

14.3.2.1 <u>Equipment Identification and Usage</u> - The instrument for obtaining the atmospheric pressure measurements is a variable capacitance device in which a pressure difference between two sides of a diaphram or membrane causes it to deflect, and the amount of deflection is detected by capacitor plates rigidly mounted near the deflecting member. The capacitance outputs are processed by an electronics circuit to provide an output signal proportional to applied pressure. Figure 14.3.2-1 presents a functional diagram of the pressure transducer.

14.3.2.2 <u>Design Requirements and Constraints</u> - The mission objectives are to make a survey of local conditions in a 27 hour period and obtain the maximum amount of useful data per data point taken. The transducing principle used must be independent of temperature phenomena as possible to determine atmospheric properties independently of each other to the maximum extent possible. The transducer must be able to withstand one atmosphere of pressure in a powered configuration without damage since prelaunch checkout procedures are, in part, conducted in Earth ambient conditions.

14.3.2.3 <u>Physical Characteristics</u> - Figure 14.3.2-2 lists the physical characteristics and Figure 14.3.2-3 presents the configuration of a typical transducer.

14.3.2.4 <u>Operation Description</u> - The operation of this transducer is based on pressure-induced deflections causing corresponding capacitance changes which result in production of a dc output voltage proportional to a ratio of the two capacitances. The sensor utilizes two capacitances to obtain linearity of output. Figure 14.3.2-4 illustrates the transducer internal configuration. A typical output circuit which will provide a dc output proportional to applied pressure is shown in Figure 14.3.2-5. A positive output from the oscillator results in a positive current being delivered to the filter capacitance (C3) and load resistor (RL) from the upper gauge capacitor (C_1) while the current from the lower gauge capacitor (C_2) is routed through a diode to ground. When the oscillator output is negative, a negative current is delivered to the filter capacitor and load resistor from the lower gauge capacitor while the upper capacitor current is passed through a diode to ground. The magnitude and direction of the capacitance difference is indicated by the magnitude and direction of the load resistor current.

During the surface mission, this sensor will be activated and read out periodically in the sequence shown in Figure 14.3.2-6 to obtain diurnal pressure variation measurements. Since the periods around sunrise and sunset are the periods of

TYPICAL PRESSURE TRANSDUCER FUNCTIONAL SCHEMATIC DIAGRAM

ATMOSPHERIC PRESSURE TRANSDUCER PHYSICAL CHARACTERISTICS

Size	2" diameter x 2" long
Volume	6.28 cubic inches
Weight	1.0 lb
Case Material	304 Stainless Steel

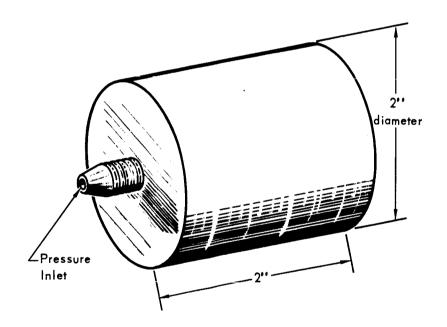## TYPICAL ATMOSPHERIC PRESSURE TRANSDUCER CONFIGURATION DRAWING

INTERNAL CONFIGURATION OF TYPICAL VARIABLE
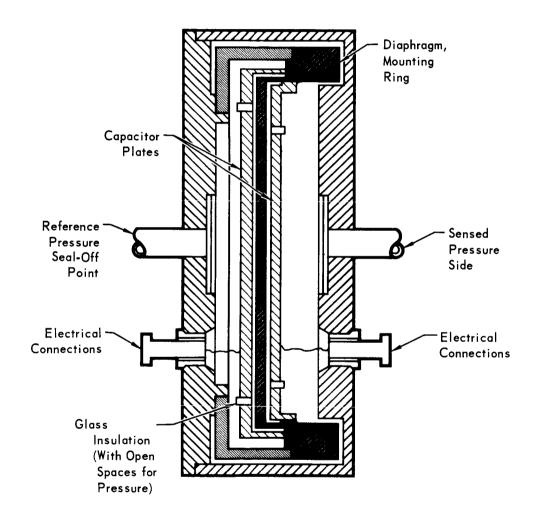## CAPACITANCE ATMOSPHERIC PRESSURE TRANSDUCER

Diaphragm,
Mounting
Ring

Capacitor
Plates

Reference
Pressure
Seal-Off
Point

Sensed
Pressure
Side

Electrical
Connections

Electrical
Connections

Glass
Insulation
(With Open
Spaces for
Pressure)

TYPICAL ATMOSPHERIC PRESSURE TRANSDUCER OUTPUT CIRCUIT

C_1, C_2 = Gauge Capacitors
C_3 = Filter Capacitor
~ = Voltage Controlled Oscillator
R_L = Load Resistor
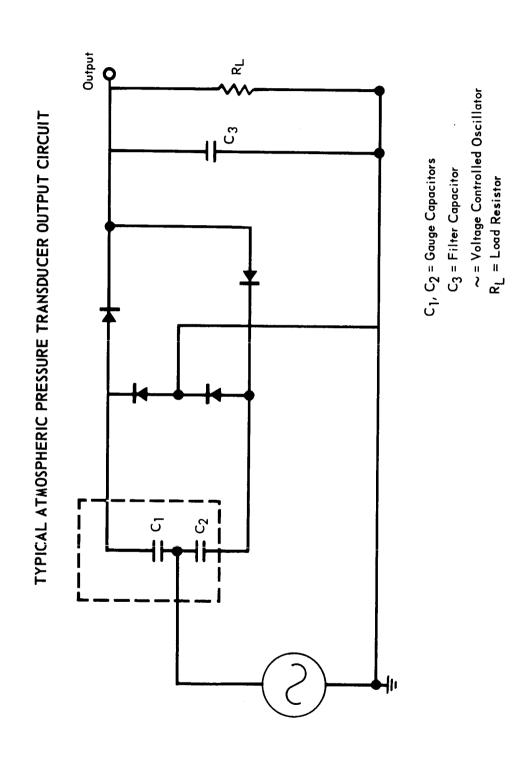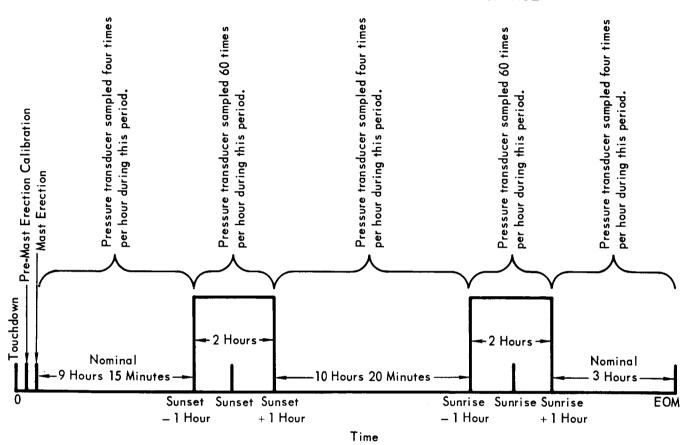
ATMOSPHERIC PRESSURE TRANSDUCER MISSION SEQUENCE

Time

largest atmospheric parameter variation, the transducer will be sampled once per minute during the periods one hour before and one hour after sunrise and sunset to observe parameter variations. During the remainder of the diurnal cycle, pressure will be measured at a rate of four samples per hour. This data will enable the reconstruction of an accurate landing site diurnal pressure profile.

14.3.2.5 <u>Performance Objectives</u> - The accuracy of the pressure transducer is ± 0.5% of full scale over the range from 0 to 0.75 psia. Resolution is limited to 0.001% of full scale, but further limitations in resolution arise when the output signal is operated on by the analog-to-digital converter in the Telemetry subsystem. Time constants impose no restrictions since worst-case time response is on the order of 50 milliseconds and removal of an input filter can reduce this by a factor of 5 or more if it becomes desirable. Stability is sufficient (6 month maximum drift is 0.1% of full scale) to preclude the necessity of a calibration after the vehicle leaves the launch pad. Figure 14.3.2-7 presents the performance characteristics of a typical atmosphere pressure transducer.

14.3.2.6 <u>Interface Definition</u> - Mounting,power, and telemetry interfaces must be compatible with this instrument as shown by the interface diagram presented in Figure 14.3.2-8. The pressure transducer is bolted to a deployable experiment mast in an area which is protected from wind gusts and wind blown dust particles.

The unit will use 28 ± 5 vdc power available from the Power subsystem and will provide an output of 0 to 5 vdc to the Telemetry subsystem. The Telemetry subsystem will perform the analog-to-digital conversion.

14.3.2.7 <u>Reliability and Safety Considerations</u> - To ensure reliable performance of the pressure transducer, a post-sterilization calibration will be performed to ensure that the reference pressure cell has remained sealed during exposure to the thermal environment of the sterilization cycle. The mounting arrangement on the Surface Laboratory will protect the transducer from shock, vibration, and acceleration loads greater than transducer design limits.

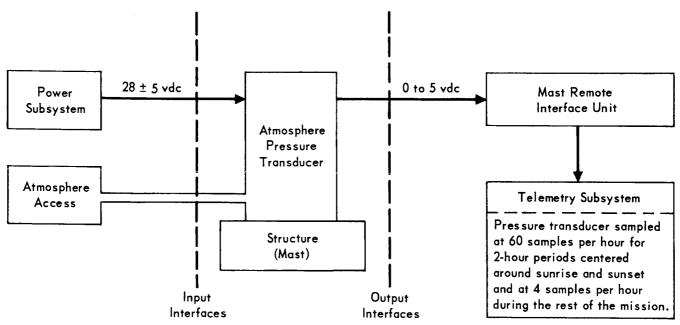Safety considerations require a burst pressure of 30 psi or more.

14.3.2.8 <u>Test Requirements</u> - No special tests other than simple voltage and continuity tests are required for this instrument during both pre-flight checkout and in-flight monitoring.

14.3.2.9 <u>Development Requirements</u> - The techniques and construction mechanisms required to implement this pressure transducer are well within state-of-the-art capabilities. Close control of welding techniques for reference cell seals is required to avoid the possibility of the reference cell leaking after exposure to

14.3-22

TYPICAL ATMOSPHERIC PRESSURE TRANSDUCER CHARACTERISTICS

PARAMETER	INSTRUMENT CHARACTERISTIC
Range	0 to 0.75 psia
Proof Pressure	23 psi
Burst Pressure	30 psi
Warm-up Time	60 secs max.
Number of Measurements	332 over a 27 hour period (60/hour for 4 hours plus 4/hour for 23 hours)
Output Signal	0 to 5 vdc, single-ended
Input Voltage	28 ± 5vdc
Input Power	1.4 watts
Time constant at 1 psi	50 msec
Accuracy	± 0.5% of full scale

ATMOSPHERE PRESSURE TRANSDUCER INTERFACE DIAGRAM

Power Subsystem

28 ± 5 vdc →

Atmosphere Pressure Transducer

Atmosphere Access

Structure (Mast)

Input Interfaces

0 to 5 vdc →

Output Interfaces

Mast Remote Interface Unit

Telemetry Subsystem
Pressure transducer sampled at 60 samples per hour for 2-hour periods centered around sunrise and sunset and at 4 samples per hour during the rest of the mission.

Figure 14.3.2 –8

14.3–24

the sterilization heat cycle.

The sterilization cycle causes a slight temporary calibration shift in the instrument. Development effort is required to determine the magnitude and duration of this effect.

14.3-25

14.3.3 <u>Atmospheric Temperature Transducer</u> - This instrument obtains periodic measurements of the atmosphere temperature on Mars during the entire surface mission.

14.3.3.1 <u>Equipment Identification and Usage</u> - The instrument employed is a platinum resistance element thermometer utilizing a resistance bridge output. A functional block diagram is shown in Figure 14.3.3-1. The measured temperatures will be correlated with time to obtain diurnal atmospheric temperature profiles.

14.3.3.2 <u>Design Requirements and Constraints</u> - The design of this instrument is influenced by two primary factors:

    o measuring the temperature of interest with a minimum of other influences,

    o and achieving both physical and operational compatibility with the interfacing subsystems.

Design of an effective atmospheric temperature transducer necessitates consideration of direct solar radiation, heat conduction and wind effects. Direct solar radiation effects can be largely eliminated by mounting the sensor in a shaded area. Heat conduction effects are compensated by placing a thermal insulation barrier between the sensor and its mounting point. Wind effects are minimized by mounting the transducer in a louvered housing on the experiment mast. SL induced effects on the measurements are minimized by locating the transducer away from the main body of the SL.

14.3.3.3 <u>Physical Characteristics</u> - The temperature transducer is a platinum resistance thermometer using a resistance bridge output circuit. The sensing element is thermally insulated from the mounting points and the bridge should be located either adjacent to the sensing element or in the mounting base. Figure 14.3.3-2 illustrates the physical shape and schematic of the sensor (and the approximate dimensions). Figure 14.3.3-3 presents the physical characteristics of the instrument.

14.3.3.4 <u>Operation Description</u> - The operation of this instrument is based upon the knowledge of the resistance-versus-temperature relationship for a particular material and a means for detecting resistance variations with changing temperature. In this case a platinum sensing element is employed and a resistance bridge is used to generate an output voltage which is proportional to the sensing element resistance. During the surface mission, this sensor will be activated and read out periodically in the sequence shown in Figure 14.3.3-4 to obtain diurnal temperature variations. Therefore, the transducer will be sampled once per minute during the one hour periods before and after sunrise and sunset. During the rest of the

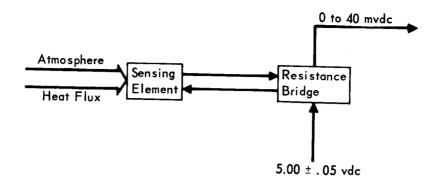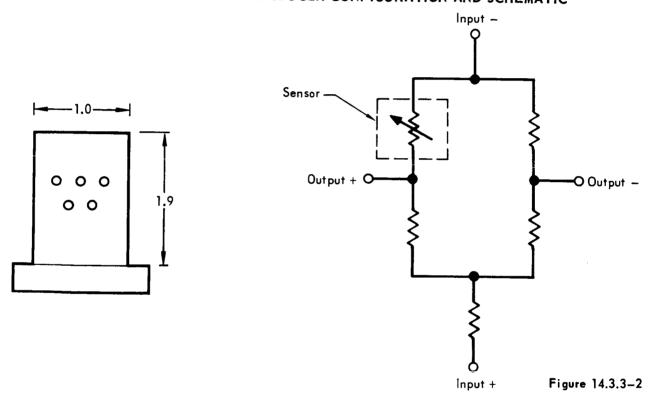# ATMOSPHERIC TEMPERATURE FUNCTIONAL BLOCK DIAGRAM

Figure 14.3.3-1

TYPICAL TEMPERATURE TRANSDUCER CONFIGURATION AND SCHEMATIC

Figure 14.3.3-2

ATMOSPHERIC TEMPERATURE TRANSDUCER PHYSICAL CHARACTERISTICS

Dimensions	1.0 in. dia x 1.9 in. long
Weight	0.5 pound total
Volume	1.7 in.^{3}

Figure 14.3.3-3

14.3-27

ATMOSPHERIC TRANSDUCER MISSION SEQUENCE

0 — Touchdown
Pre-Mast-Erection Calibration
Mast Erection

Nominal
(9 hr –
15 min)

Temperature Transducer
Sampled 4 Times Per Hour
During This Period.

Sunset
–1 hour

2 hr

Temperature Transducer
Sampled 60 times per hour
during this period.

Sunset

Sunset
+ 1 hour

10 hr –
20 min

Temperature Transducer
Sampled 4 Times per hour
during this period.

Sunrise
– 1 hour

2 hr

Temperature Transducer
Sampled 60 times per hour
during this period.

Sunrise

Sunrise
+ 1 hour

Nominal
(3 hr)

Temperature Transducer
Sampled 4 times per hour
during this period .

EOM

surface mission the transducer will be sampled at a rate of four samples per hour. This will provide data for an accurate reconstruction of the diurnal temperature profile at the landing site.

14.3.3.5 <u>Performance Objectives</u> - The accuracy of the temperature sensor is ± 1.0% of full scale over the range from 150° to 330°K. Although the element sensitivity to temperature change is infinite, the parameter quantization accuracy is limited by the Science Data Subsystem. Sensor interchangeability and stability are sufficient to preclude the necessity of calibration with every element change or extended duration non-operating period. Characteristics of the transducer are shown in Figure 14.3.3.5.

14.3.3.6 <u>Interface Definition</u> - Mounting, radiation shielding, power, and telemetry interfaces are satisfied for this instrument as illustrated by Figure 14.3.3-6 which shows the interface diagram for the temperature transducer.

The mounting interface exists inside a louvered compartment atop the experiment mast. The mounting flange will be either a bond-on or bolt-on piece having dimensions compatible with space available and sensor environmental requirements. The conduction shield is part of the transducer rather than in the transducer/mast interface, so that thermal characteristics of the mounting interface are not of paramount importance.

The radiation shielding requirement is satisfied by placing the transducer inside the louvered container and orienting the louvered compartment such the louver angle/solar angle relationships prevent solar radiation from impinging on the sensor.

Both 28 ± 5 vdc and 5.00 ± 0.05 vdc sources are available from the SL power system. The temperature transducer will use the 5.00 ± 0.05 vdc level rather than the 28 ± 5 vdc level because of regulation and temperature transducer self-heating considerations.

The signal from the resistance bridge is a 0 to 40 mvdc double-ended output which is hardwired to the Telemetry subsystem for multiplexing and analog-to-digital conversion.

The internal interface for the temperature sensor consists of a two wire connection between the sensing element and the bridge.

14.3.3.7 <u>Reliability and Safety Considerations</u> - To ensure reliable performance the mounting provisions for the temperature sensor must protect the sensor from shock, vibration, and acceleration loads greater than sensor design limits. There are no safety requirements peculiar to the inclusion of this transducer in the SL.

TEMPERATURE TRANSDUCER CHARACTERISTICS

Range	$150°K$ to $330°K$
Type	Resistance Thermometer with Annealed Platinum Sensing Element
Input Voltage	$5.00 \pm .05$ Vdc
Output Voltage	0 to 40 mvdc, double-ended
Accuracy	$\pm 1\%$ Full Scale
Number of Measurements	4/hour for 23 hours plus 60/hour for 4/hours – 332 total
Installed Location	Inside Louvered Compartment On Deployable Mast

Figure 14.3.3–5

ATMOSPHERIC TEMPERATURE TRANSDUCER INTERFACE DIAGRAM
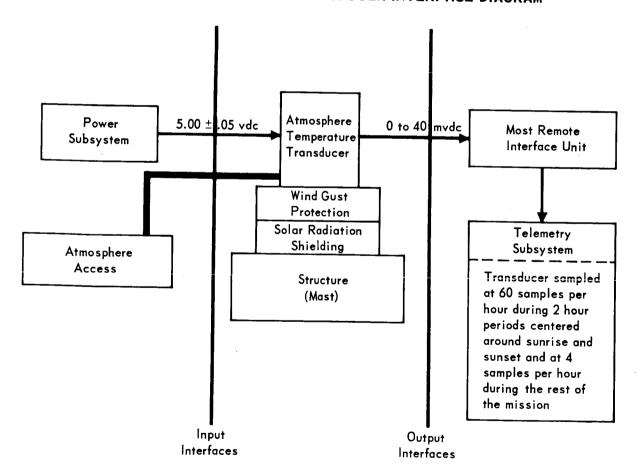
Figure 14.3.3–6

14.3.3.8 <u>Test Requirements</u> - Preflight test requirements consist of standard voltage and continuity checks. There are no special in-flight checkout and monitoring requirements.

14.3.3.9 <u>Development Requirements</u> - All the techniques and materials required to implement this instrument are existing, therefore, no advanced development is required to meet the temperature transducer requirement.

14.3.4 <u>Atmospheric Humidity Transducer</u> - This instrument obtains periodic measurements of the atmospheric humidity on Mars during the entire surface mission.

14.3.4.1 <u>Equipment Identification and Usage</u> - The humidity readings obtained will be correlated with time to obtain diurnal atmospheric humidity profiles. This data, together with data generated by other SL science instruments (surface, atmospheric, and subsurface), will be correlated to provide an insight into the physical processes occurring on Mars.

The instrument used to obtain the diurnal cycle humidity measurements is a dew/frost point hygrometer with an impedance bridge output circuit. Figure 14.3.4-1 is a functional schematic diagram of the hygrometer.

14.3.4.2 <u>Design Requirements and Constraints</u> - The mission objectives, as applied to this instrument, are to make a landing site survey of atmospheric humidity conditions over a 27 hour surface operation period. The unit must be sterilizable per the NASA specifications and must be able to operate in an Earth environment. The heat sterilization cycle requires that the unit design satisfy three additional requirements:

  o nonoperating pressures of 23.0 psi, and

  o long term nonoperating exposure to elevated temperatures, and

  o adjustment features if the heat cycle causes some electronics shifts.

In addition to the above requirements, the transducers must tolerate without performance degradation, all natural and induced environments encountered.

14.3.4.3 <u>Physical Characteristics</u> - The hygrometer used to obtain the humidity profile measurements consists of an aluminum oxide sensing element which is connected to an impedance bridge. The bridge output is rectified, filtered, and run through a differential amplifier for conditioning to a level compatible with the Telemetry subsystem input interface. The unit, excluding the sensor, is contained in an assembly approximately four inches in diameter and 0.75 inches thick. The mounting attachment for the sensor has not been determined, but the sensor itself is approximately 0.25 x 0.5 x 0.04 inches. Figure 14.3.4-2 lists the physical characteristics and Figure 14.3.4-3 presents a configuration drawing of the hygrometer.

14.3.4.4 <u>Operation Description</u> - The aluminum oxide sensing element consists of an anodized aluminum plate which has a thin gold layer evaporated on its porous aluminum oxide layer. The aluminum plate and gold film form two plates of a capacitor. Water vapor passes through the gold layer and changes the impedance characteristics of the capacitor. The primary influence on the impedance change is the surface

ATMOSPHERIC HUMIDITY INSTRUMENT
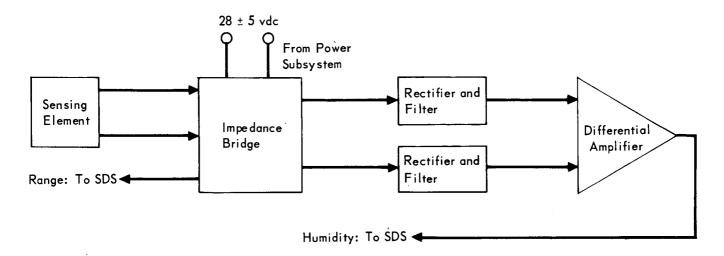## FUNCTIONAL SCHEMATIC DIAGRAM

28 ± 5 vdc

From Power
Subsystem

Sensing
Element

Impedance
Bridge

Rectifier and
Filter

Rectifier and
Filter

Differential
Amplifier

Range: To SDS

Humidity: To SDS

Figure 14.3.4–1

HYGROMETER PHYSICAL CHARACTERISTICS

CHARACTERISTIC	ELECTRONICS	SENSOR
Dimensions	4.0" dia x 0.75" thick	0.25" x 0.5" X 0.04"
Volume	9.42 in.^{3}	.005 in.^{3}
Weight	1.0 lb	10^{-2} lb

Figure 14.3.4–2

NOMINAL HYGROMETER CONFIGURATION DRAWING

Connector

Sensing Element
(.5 In. x .25 In. x 0.04 In.)
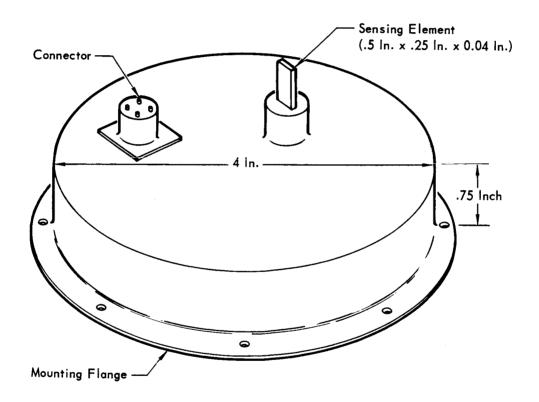
4 In.

.75 Inch

Mounting Flange

Figure 14.3.4-3

14.3-34

resistance change in the aluminum oxide pores as water is absorbed on them. Impedance of the sensor is measured by an impedance bridge whose output is then rectified, filtered, and passed through a differential amplifier. Figure 14.3.4-4 defines the mission sequence and Figure 14.3.4-5 presents the instrument characteristics of the hygrometer.

During the surface mission, this sensor will be activated and read out periodically to obtain diurnal humidity variation measurements. Since the periods around sunrise and sunset are the periods of greatest atmospheric parameter variation, this transducer will be sampled once per minute during the one hour periods before and after sunrise and sunset. During the remainder of the diurnal cycle the transducer will be sampled at a rate of four samples per hour. This data will permit reconstruction of an accurate landing site diurnal humidity profile.

14.3.4.5 Performance Objectives - The accuracy of this transducer will be such that frost points in the lowest operating range of the instrument are determined to $\pm 2°C$ and to within $\pm 0.5°C$ at the highest operating range. The response time of the instrument must be on the order of seconds or less so that humidity variations in the periods of maximum humidity change can be detected. Instrument stability characteristics must be small enough to allow this transducer to be used with confidence during the Mars surface mission.

14.3.4.6 Interface Definition - Mounting, power, thermal, and telemetry interfaces must be compatible with this instrument as illustrated by the interface block diagram presented as Figure 14.3.4-6.
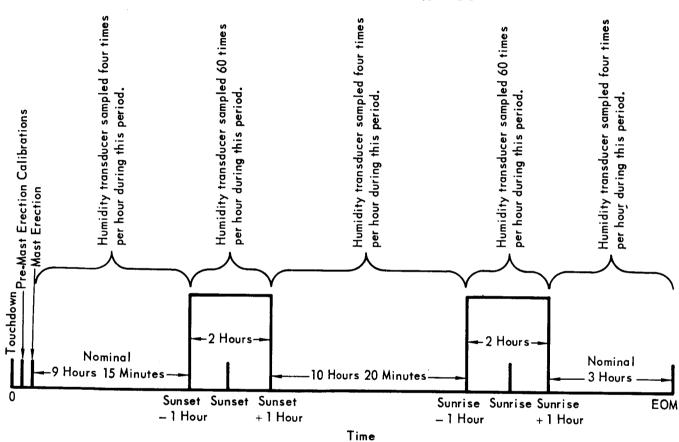
The instrument is mounted inside the louvered container on the experiment mast. The temperature inside this container at the sensor location will be at equilibrium with the surrounding atmosphere temperature so that local heating and cooling effects will not destroy the interpretability of the humidity measurements.

The hygrometer will use 28 ± 5 vdc power available from the Power subsystem. Any voltage level changing or regulation required beyond the 28 ± 5 vdc will be performed by the hygrometer electronics.

The sensing element will operate over the entire range of ambient temperatures anticipated. However, the electronics will probably require a thermostatic heater to maintain the electronics temperature at $0° \pm 50°C$.

The output to the data subsystem will be raised to a 0 to 5 vdc signal by the differential amplifier in the output circuit of the hygrometer. There may be more than one bridge frequency utilized to provide extra resolution in some areas of the

14.3-35

HUMIDITY TRANSDUCER MISSION SEQUENCE

Touchdown

Pre-Mast Erection Calibrations

Mast Erection

Humidity transducer sampled four times per hour during this period.

Humidity transducer sampled 60 times per hour during this period.

Humidity transducer sampled four times per hour during this period.

Humidity transducer sampled 60 times per hour during this period.

Humidity transducer sampled four times per hour during this period.

Nominal
9 Hours 15 Minutes

2 Hours

10 Hours 20 Minutes

2 Hours

Nominal
3 Hours

0

Sunset
− 1 Hour

Sunset

Sunset
+ 1 Hour

Sunrise
− 1 Hour

Sunrise

Sunrise
+ 1 Hour

EOM

Time

Figure 14.3.4—4

14.3—36

TYPICAL ATMOSPHERIC HUMIDITY INSTRUMENT CHARACTERISTICS

PARAMETER	INSTRUMENT CHARACTERISTICS
Range	Dew/Frost Points from −110°C to + 30°C
Warm-up Time	60 Seconds Maximum
Number of Measurements	332 Over a 27 Hour Period (60/Hour for 4 Hours Plus 4/Hour for 26 Hours)
Input Voltage	28 ± 5 VDC
Input Power	1.0 Watt Maximum
Output Voltage	0 to 5 VDC Single Ended
Output Impedance	2,000 ohms Maximum
Response Time	30 Seconds Maximum
Accuracy	± 2°C at −110°C Frost Point to ± 0.5°C at 30°C Dew Point
Operating Temperature	Sensing Element −110°C to + 60°C Electronics − 50°C to + 50°C
Operating Pressure	0 to 15 psia
Non-Operating Pressure	0 to 23 psia
Gas Flow Velocity	10 m/Sec. Maximum

Figure 14.3.4−5

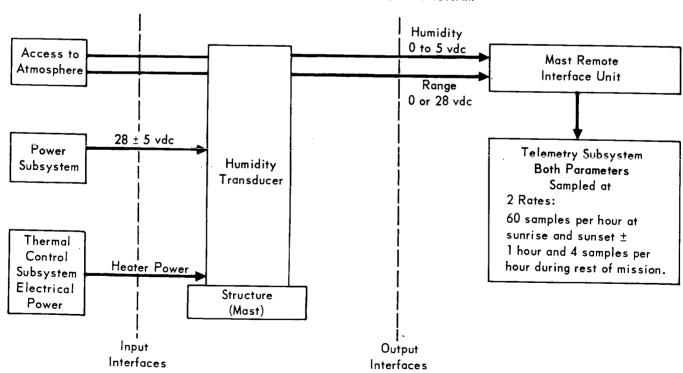## HUMIDITY TRANSDUCER INTERFACE DIAGRAM

Figure 14.3.4−6

14.3−37

instrument spectrum. If this proves to be the case, a bilevel signal of 0 or 28 vdc magnitude, indicative of oscillator frequency, will be telemetered.

14.3.4.7 <u>Reliability and Safety Considerations</u> - To ensure reliable operation of the hygrometer, certain considerations have been given particular attention. The use of a two frequency oscillator permits the instrument to experience a single frequency failure and continue to function at a degraded performance level for the rest of the mission. Electronics stability can be verified by adding a known impedance to be periodically switched into the bridge and read out if development tests indicate this to be desirable to maintain performance levels within design limits. There are no special safety considerations for this instrument.

14.3.4.8 <u>Test Requirements</u> - Pre-flight and inflight test requirements include:
  o simple voltage and continuity checks, and
  o an operational run with a fixed impedance supplying an electrically
     simulated humidity input.

14.3.4.9 <u>Development Requirements</u> - The aluminum oxide hygrometer has been used for a number of years. Units are available for use in laboratories and efforts are under way to develop a sensor and electronics unit for space applications. The primary effort required is to develop a unit sensitive enough to detect anticipated Mars moisture levels.

14.3.5 <u>Atmospheric Wind Transducer</u> - The wind instrumentation, contained in the atmospheric package, senses the wind velocity and direction of the free stream at a height of approximately five feet above the surface. Based on the VM-7 and VM-8 atmosphere models, the velocity is expected to range from 0 to 450 ft/sec at this altitude. The data obtained from the wind measurements should allow local wind profiles of velocity and direction to be estimated over one diurnal cycle. Local surface roughness conditions will have a significant effect on the wind characteristics at the sampling location.

14.3.5.1 <u>Equipment Identification and Usage</u> - The wind instrumentation is packaged with the atmospheric pressure, temperature and humidity sensors in the lower portion of the atmospheric package. The entire group is deployed near the end of the low rate S-band antenna mast after landing. The basic components employed for measuring the Mars surface wind include the following:

- ° Three hot-wire anemometers mounted horizontally in supporting structure which is attached below the solid cylindrical portion of the atmospheric package to resolve winds with velocities below 150 ft/sec and provide vector information. One hot-wire anemometer is mounted vertically to sense horizontal winds from all directions.

- ° Two dynamic pressure sensing drag plate anemometers are each suspended by a sting cantilevered from the bottom to resolve winds with velocities in the range of 150 to 450 ft/sec.

- ° Electronics package servicing all the anemometers.

A functional block diagram is shown in Figure 14.3.5-1.

In addition to the anemometers, a similar hot wire mounted in a static chamber is used to provide an ambient temperature measurement which is needed for scaling the hot-wire anemometer measurements. This static port is open to the atmosphere but shielded from the wind. Because of the small additional weight and increased reliability, a redundant set of hot-wire anemometers is included with the instruments. The most probable failure is a broken wire which is sensed by the electronics and automatically switched to the second set of wires.

14.3.5.2 <u>Design Requirements and Constraints</u> - The major design consideration involving successful operation of the wind instrumentation, is having the atmospheric package fully deployed into the free wind stream after landing. Package deployment positioning must not interfere with other SL subsystems such as the high gain directional antenna or spectral radiometer. Leveling of the instrument is desirable but not necessary. An indication of the orientation of the package

14.3-39

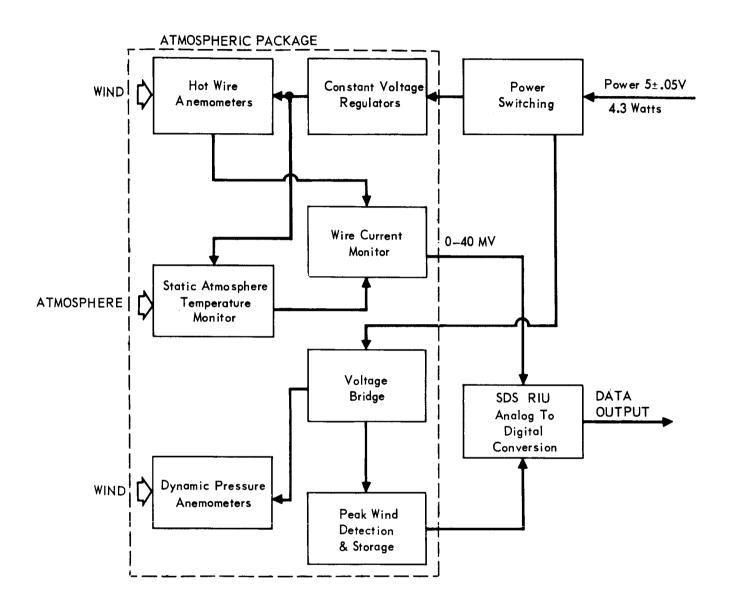# WIND INSTRUMENTATION FUNCTIONAL ARRANGEMENT

Figure 14.3.5-1

14.3-40

with respect to local vertical and geographic coordinates will aid considerably in the final data analysis.

All wind sensors must be positioned within the package such that perturbation of the free wind stream by structural components is minimized. An initial calibration is required prior to deployment of the mast to establish baseline operation parameters in a windless environment. The SL Power, Computer and Sequencer, and Data subsystems must be operable prior to deployment of the sensors.

Final wind data analysis will depend on valid atmospheric pressure, temperature and composition measurements, because the sensitivity of both types of anemometers is a function of the density of the atmosphere. Failure to obtain any one of these measurements will degrade the accuracy of the wind measurements.

14.3.5.3 Physical Characteristics –

° Hot-wire anemometers – The sensor element of the hot-wire anemometers typically consists of a 0.002 inch diameter platinum wire stretched between two thermally insulated support members. The length of the wire is 0.25 inches. The wire is encapsulated in a quartz shield approximately .02 inch diameter to protect the wire from wind blown particles and increase structural integrity.

° Dynamic Pressure Sensors – The pressure plates of the high velocity sensors are titanium measuring 1 inch on the sides by 0.02 inches thick.

Thin film strain gages are bonded to each side of the stings near the cantilevered edge to measure the amount of deflection which is proportional to the square of the wind velocity. The pressure plates are mounted vertically with their planes perpendicular to each other.

The arrangement of the wind instrumentation is shown in Figure 14.3.5-2. The direction sensor geometry consists of three hot-wire anemometers mounted horizontally in a plane such that there is 120° separation between adjacent sensors. The component wind velocity measured by each sensor is proportional to the sine of the incident angle. The sensors are mounted as near the periphery of the atmospheric package as possible to minimize the effects of structural interference with the free stream.

The omnidirectional sensor is mounted in a vertical plane, in a position relatively free from wind disturbance.

A redundant set of hot-wire anemometers is included with the same geometry as the primary sensors. All the electrical wiring is contained in the structure and routed to the electronics package above the anemometers.
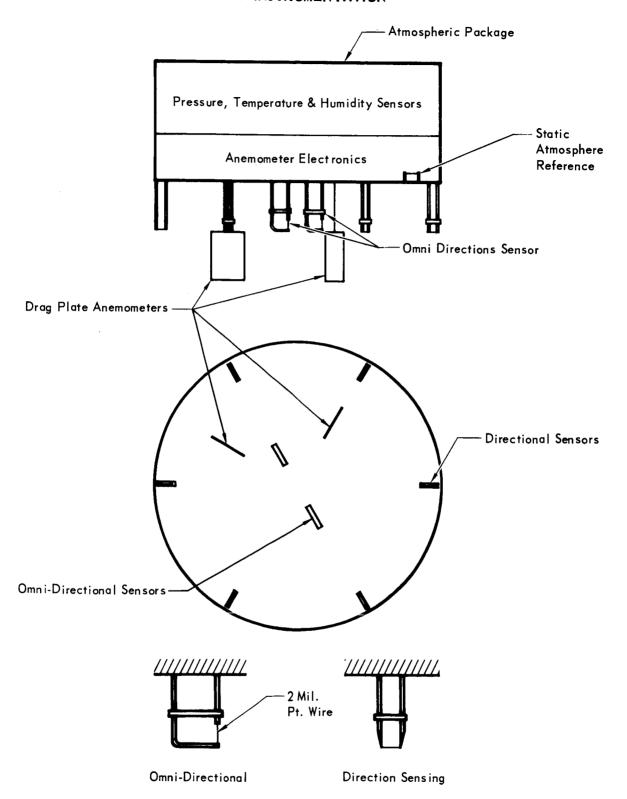
14.3-41

WIND INSTRUMENTATION

Figure 14.3.5-2

14.3-42

The power, size and weight characteristics of the wind instrumentation are shown in Figure 14.3.5-3.

14.3.5-4 Operation Description

° Hot-Wire Anemometers - The hot-wire anemometer operation is based on the cooling of a wire which is heated to a temperature above that of the ambient atmosphere by controlling the current through it. There are basically three methods of operating the anemometer to obtain a signal which is correlatable to the wind velocity. The method selected is that of maintaining a constant voltage across the wire while the current varies as the temperature of the wire changes. This method is the most economical in the power required at a slight expense of accuracy over the other methods, e.g., maintaining a constant current through the wire. The wind instrumentation functional arrangement appears in Figure 14.3.5-1. Each hot-wire anemometer and the temperature reference wire has a constant voltage supply to furnish the heating power. The amount of current passing through the wire is measured across a temperature compensated bridge for sampling by the data system. The analog signal output of the bridge ranges from 0 to 40 mV. An open circuit sensor is provided to automatically switch the electronics to the second set of anemometers in the event any of the hot-wire circuits open up. The switching can occur only once if a failure is detected. The data from each hot-wire anemometer is an instantaneous value at the time it is sampled by the data system, as opposed to the peak measurement of the pressure anemometer.

° Pressure Anemometers - Winds in excess of 150 ft/sec are resolved by the pressure anemometers. The overpressure created by the drag causes the sting to deflect by an amount proportional to the square of the wind velocity. The amount of deflection is measured by full bridge, thin film strain gage sensors which are bonded to each side of the sting near the cantilevered edge. The sensitivity of the pressure anemometers is expected to include velocities somewhat less than 100 ft/sec.

The analog signals from the hot-wire anemometers are fed directly into the Remote Interface Unit for A/D conversion. Comparator circuits hold the largest signals from the pressure anemometers sensed between sampling. This maximum signal is presented to the Remote Interface Unit for A/D conversion.

Programmed operation of the wind instrumentation is accomplished by switching the power to and from the instruments. A 30 second warm-up time is required be-

14.3-43

WIND INSTRUMENTATION TABLE OF PHYSICAL CHARACTERISTICS

ITEM	SIZE (in.)	WEIGHT (lb)	Power (watt)	Volume (in.^{3})	Energy (watt hr)	Data (Total bits)
Hot Wire Anemometers and Temperature Monitor	0.25 x 0.02 dia	0.3	2.0		11.0	31,680
Pressure Anemometers	1 x 1 x 0.02	0.2	0.3		8.1	5,184
Electronics	1 x 6 dia	1.0	2.0	28	11.0	
Support Structure	1 x 6 dia	0.5		28		
Total		2.0	4.3	56	30.1	3,6864

fore data sampling. Figure 14.3.5-4 represents a typical mission sequence which provides adequate measurements during expected times of rapidly changing wind characteristics, optimizing the power and data loads.

14.3.5.5 Performance Objectives - The design range of wind velocity at a height of three meters above a smooth surface is from 0 to 450 ft/sec. The wind instrumentation is expected to measure winds within this range; however, winds less than 100 ft/sec are considered more probable.

For winds up to 150 ft/sec the velocity accuracy is $\pm$15% and direction resolution $\pm$5° falling into the measurement range of the hot-wire anemometers.

The operation of the pressure anemometers is expected to include wind velocities involving Reynolds Numbers in excess of 100. For the preferred geometry this would correspond to velocities as low as 40 ft/sec in the lowest density atmosphere. The threshold sensitivity will be limited by the threshold of the strain gage system.

14.3.5.6 Interface Definition - Interfaces of the wind instrumentation with the SL are shown in Figure 14.3.5-5. The supporting SL subsystems are:

o Power - Regulated 5 $\pm$ 0.05 vdc

o Computer and Sequencer - Programmed on-off commands for power switching

o Science - 0 - 40 mv signals to the Remote Interface Unit

14.3.5.7 Reliability and Safety Considerations - Reliability considerations require proper mounting and adequate deployment techniques to insure that the instruments are capable of withstanding maximum shock and acceleration environments. Thermal control should pose no limitations. The overall reliability is expected to exceed .9.

The hot-wires must not be turned on during the sterilization process in inflammable gas environments.

14.3.5.8 Test Requirements - Low pressure wind tunnel runs will be made to calibrate all the wind sensors prior to installation and sterilization. A test control unit will be required to furnish the equivalent SL power, control and data readout interfacing.

Static atmosphere check runs will be made post sterilization and installation for functional testing and static point calibration. Vibration and shock testing will be required during the early development to establish a mount design which minimizes the probability of wire breakage.
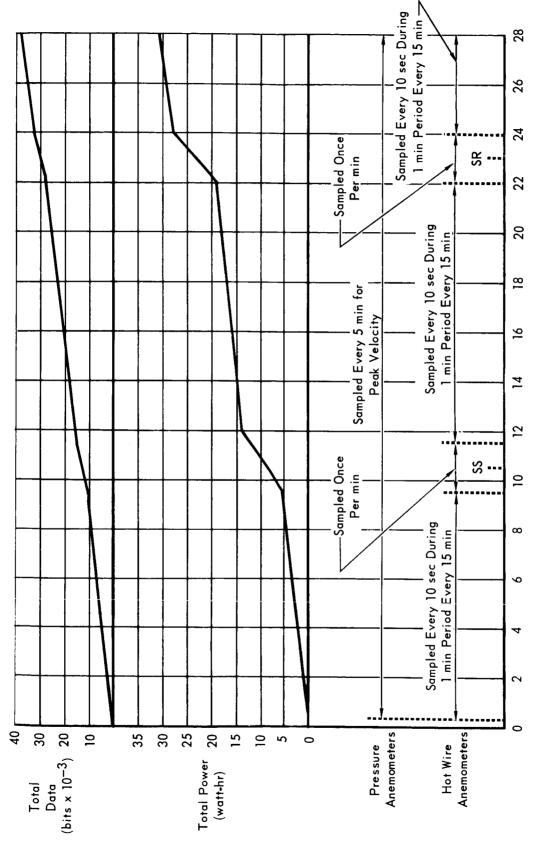
14.3-45

WIND MEASUREMENT MISSION SEQUENCE

Figure 14.3.5-4

WIND INSTRUMENTATION INTERFACES

```
┌──────────┐      ┌──────────────┐              ┌──────────────┐
│ Power    │ ───▶ │ Power        │ ─────────────▶ │ Wind         │
│ (5V DC)  │      │ Switching and│              │ Instrumentation│
│          │      │ Sequencing   │              │              │
└──────────┘      └──────────────┘              └──────────────┘
                                                       │
                                                       │ Analog Data
                                                       │ 0–40 mV
                                                       ▼
┌──────────┐                    Digital Data    ┌──────────────┐
│ Data     │ ◀──────────────── (8 Bits/Sample)  │ SDS RIU      │
│ System   │                                    │ Analog       │
│          │                                    │ to Digital   │
│          │                                    │ Converter    │
└──────────┘                                    └──────────────┘

   SURFACE LABORATORY          LOW RATE S-BAND ANTENNA MAST
```
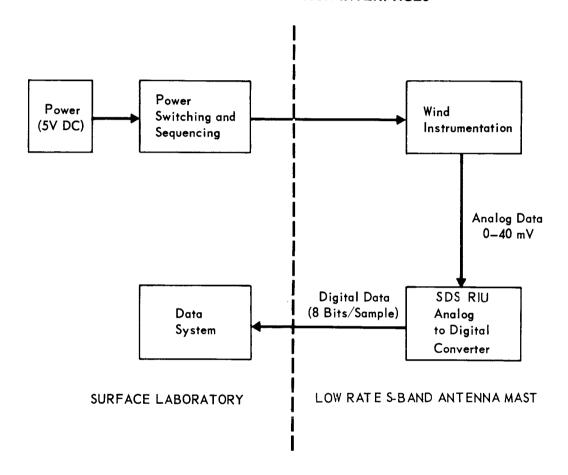
Figure 14.3.5–5

14.3–47

14.3.5.9 <u>Development Requirements</u> - Attention is currently being directed to the development of wind instrumentation capable of withstanding shock, dust and blowing sand environments. This will involve developing satisfactory mounts and shields for the hot-wire anemometer.
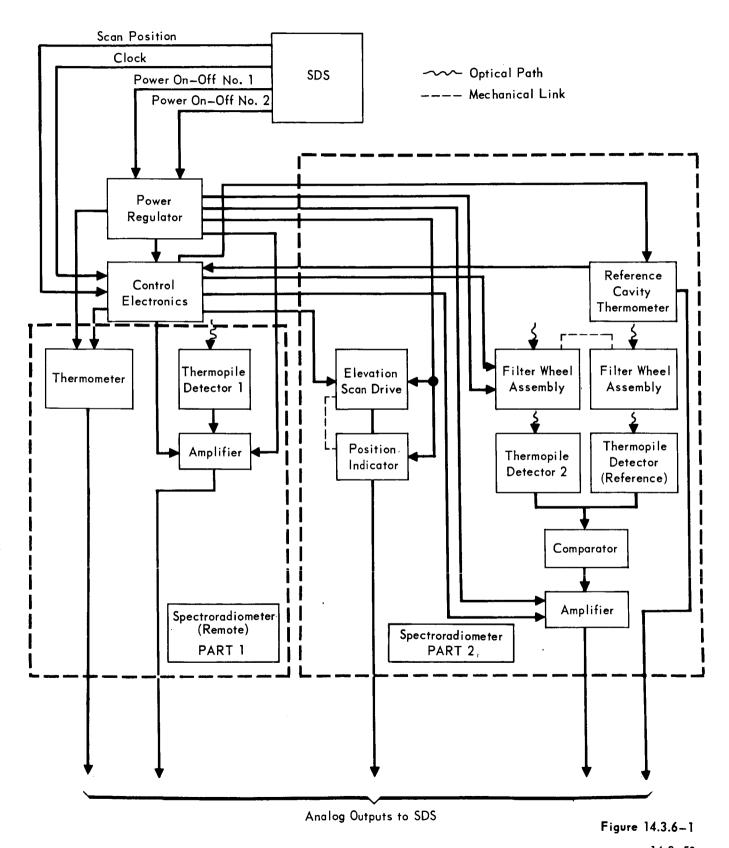
14.3.6 Spectro Radiometer

14.3.6.1 Equipment Identification and Usage - The spectro radiometer consists of
two parts, as shown in the schematic block diagram in Figure 14.3.6-1. Part 1 is
a simple wide field radiometer capable of measuring the total radiant flux inci-
dent from the sky. This data is used to evaluate isolation at the surface of Mars.
Part 2 performs directional spectral measurements. It breaks the spectral region
from the ultraviolet through the infrared into 34 spectral bands. A 30° field of
view and elevation gimbal provides directional capability. Part 2 is pointed at
the overhead sky (to establish a correlation with Part 1) as well as far/near sur-
face regions and the horizon (to evaluate radiation exchange).

Part 1, Spectro Radiometer (remote) - Part 1 is installed on a self erecting
pivot which allows its optical axis to point at the local zenith. The unit is
turned on by a command from the Science Data Subsystem (SDS). Radiation incident
from the sky falls on a 20 element thermopile detector which generates an analog
d.c. signal. This signal is amplified, and then fed to a SDS digitizer. Signal
levels are temperature dependent, thus detector temperature is monitored. Reading
times are short and occur every 15 minutes throughout the duration of the mission.

Part 2, Spectro Radiometer - Part 2 operates on a programmed sequence which
samples the radiation arriving from 4 different directions. This energy falls on
a thermopile detector (identical to Part 1) after passing through a spectral filter
which limits its wavelength bandpass. The resulting electrical signal is fed to a
comparator where it is subtracted from the output of an identical reference channel.
This reference channel has a complementary set of components and operates in syn-
chronization with the detection channel. The only difference between the two is
that the reference channel views an internal black body and nothing outside. Following
the comparison process the analog difference signal is amplified, converted to an
ac carrier and sent on to the SDS for digitizing. Calibration is established by
measuring the temperature of the reference black body. This sampling is repeated
for each of 34 spectral bands using a filter wheel. A clear (total energy) slot
is available to relate these outputs with those of Part I. A blank slot serves as
position reference.

Completion of spectral sampling at one direction leads to a command directing
Part 2 to a new pointing location. This is accomplished by a stepper motor scan
drive. An electro-mechanical indicator provides an analog position signal. Seven
of these 4 directional settings are performed in a 27 hour period.

14.3-49

FUNCTIONAL SCHEMATIC BLOCK DIAGRAM
SPECTRO RADIOMETER

Figure 14.3.6-1

14.3-50

14.3.6.2 <u>Design Requirements and Constraints</u> - Practical considerations dictate a two part system in lieu of a single unit. The small Part 1 is placed on the low rate S-Band antenna mast where its location ensures a clear 120° view of sky regardless of the SL orientation. Part 2 is situated on the main SL deck where it requires minimum support. Unobstructed elevation viewing is obtainable over the major portion of its 180° pointing range.

Thermopile detectors generate a signal whose magnitude is dependent upon thermal heating. This energy input can come both from the scene radiation and the emission from the surrounding background. Only the former radiation is of interest, the latter must be calibrated out. In Part 1 this is accomplished by evaluating thermopile sensitivity over the expected operating temperature range. A thermometer supplies the information necessary to correlate operational conditions with the calibration. Part 2 uses an electro-optical bridge configuration, to secure independence from background temperature effects. Although both of these approaches free the sensing process from tight thermal control, some small non-linearities and changes in sensitivity do exist. For this reason the external surfaces of the detector packages are coated with thermally reflective gold to minimize transients and insure a more stable internal environment.

The optical field must be free from extraneous warm objects during measurements. These objects, whether they are opaque like an antenna or minute like an aerosol, will distort the measurements. As these sensors evaluate only energy, there is little concern for small movements during sampling. Electrical regulation and shielding from intense RF energy is not a particular problem due to the simplicity of the circuits. Data rates are low and cycle rates are also low.

14.3.6.3 <u>Physical Characteristics</u> - The location of this instrument on the SL is shown in Figure 14.3.6-2. Part 1 is positioned on a mast with the antenna. Part 2 is located on the top and at one corner of the main SL structure.

The physical features of the spectro radiometer are also shown in Figure 14.3.6-2. The 0.5 pound Part 1 is housed in a 1.5 inch diameter by 3 inch long cylindrical shell. The detector/amplifier package and its erection gimbal fit in this shell. Including the structural attachments, this assembly approximates 15 cubic inches in volume. The sensing/processing section of Part 2 is housed in a cigar shaped package 6 inches long and 4 inches in maximum diameter. Positioning is accomplished through a stepper motor/gimbal assembly located in the pivot structure. The pivot axis is approximately 6 inches above the SL surface. Both
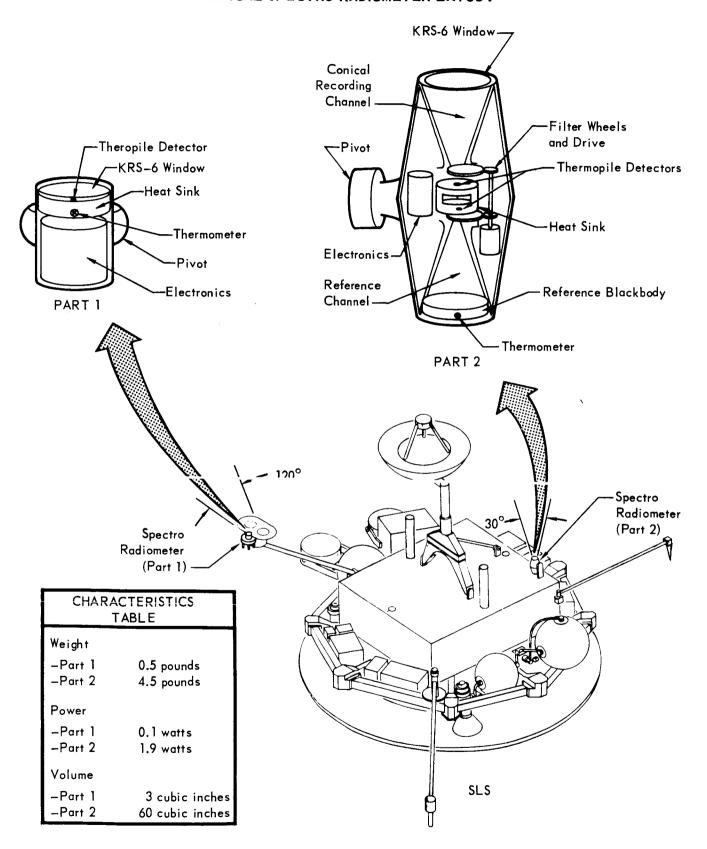
TYPICAL SPECTRO RADIOMETER LAYOUT

KRS-6 Window

Conical
Recording
Channel

Pivot

Filter Wheels
and Drive

Thermopile Detectors

Electronics

Heat Sink

Reference
Channel

Reference Blackbody

Thermometer

PART 2

Theropile Detector

KRS-6 Window

Heat Sink

Thermometer

Pivot

Electronics

PART 1

120°

30°

Spectro
Radiometer
(Part 1)

Spectro
Radiometer
(Part 2)

SLS

CHARACTERISTICS TABLE	
Weight	
—Part 1	0.5 pounds
—Part 2	4.5 pounds
Power	
—Part 1	0.1 watts
—Part 2	1.9 watts
Volume	
—Part 1	3 cubic inches
—Part 2	60 cubic inches

Figure 14.3.6–2

14.3–52

Parts 1 and 2 receive their radiant energy through thin KRS-6 protective windows. The weight, volume, and power requirements of these units are summarized in the Characteristics Table included with Figure 14.3.6-2.

14.3.6.4 **Operational Description** - Part 1 is freed following mast erection and immediately starts a sampling sequence consisting of one 15 second measurement every 15 minutes. Recording occurs once a second for the last 5 seconds of each run, the first 5 seconds being devoted to warmup; the second includes a calibration period. This sequence continues day and night for 27 hours completely spanning one Martian diurnal cycle. Spectral sampling with Part 2 is less frequent occurring only 28 times during the same period. However, the measurement interval is longer (72 seconds, 2 samples/second) and directional pointing is provided after each reading interval. Four regions are covered in one grouping and include areas of the sky, ground, and horizon. Each grouping takes place seven times. Programming is such that Parts 1 and 2 do not operate at the same time, thus minimizing power and handling requirements. Correlation between the units is possible when Part 2 views the overhead sky as the energy levels are directly related to the solid angle of the optical cones.

14.3.6.5 **Performance Objectives** - The solar isolation measurements conducted by Part 1 are spectrally limited only by source energy conditions and the transmittance of KRS-6. They extend from 0.2 to 30 microns. The spectral readings in Part 2 break this wavelength region into 34 parts. Five bands, having wavelength intervals of 0.1 - 0.2 microns, appear below 1.0 micron. Twenty-nine bands, each 1.0 micron wide, occur between 1.0 and 30 microns. A representative listing of signal to noise ratios (emissive source) for the preferred thermopile spectro radiometer appears below:

Blackbody Temperature	Peak Emmittance	Peak Wavelength	Spectral Signal to Noise Ratio		
			3 microns	10 microns	30 microns
(-25°) 250°K	10^{-3} w/cm^2	12 microns	40	100,000	20,000
(CO_2) 200°K	4×10^{-4} w/cm^2	14 microns	1	30,000	15,000

Conditions:	Bandwidth:	1 hertz
	NEP:	7.6×10^{-10} watts
	Detector Area:	0.06 cm^2
	Wavelength Interval:	1 micron
	Integration Time:	1 second

14.3-53

Reflected solar inputs during the daytime will lead to comparable ratios at the visible and ultraviolet wavelengths. These are adequate to accomplish the experimental objectives.

14.3.6.6 <u>Interface Definition</u> - Interface requirements appear in Figure 14.3.6-3. Reference to this figure shows the spectro radiometer to require little support except in commanded operation and data handling.

14.3.6.7 <u>Reliability and Safety</u> - The spectro radiometer is a very simple system designed with current technology and proven techniques. There are no moving components in the detection channels of either Part 1 or 2 with the exception of the filter wheels in the latter. These are driven by direct gearing and environmentally proven motors. If the motor fails completely, partial experimental success is assured since the wheels always stop on an open view. Single color evaluations can thus be continued.

The window material, KRS-6, is adequate for this application. Surface erosion could occur under extreme wind-driven aerosol conditions. Energy measurement is the prime objective, however, and this degradation changes only the solid angle dependence resulting in a gradual loss of precision. The material's melting temperature is 424°C, well above the 135°C experienced in steriliztion.

The erection and pointing mechanism employs simple sealed gears and bearings. Component failure limits only the pointing feature, not the detection capability.

To avoid surface contamination of the optical windows during sterilization, both spectro radiometer parts require removable covers. These can be designed as part of the stowage/erection mechanisms, coming off when the units are freed and readied for operation.

14.3.6.8 <u>Test Requirements</u> - Major testing of the instrumentation will include radiometric calibration of the detectors, electrical checkout of the detection/command circuits, and mechanical verification of the ability to erect/scan. A thorough assessment of all parameters will be conducted prior to CBS steriliaztion. Radiometric tests use a calibrated blackbody thermal standard and correlate detector detectivity with source temperature as a function of detector temperature. Electrical evaluations center mainly on the measurement of bias levels, synchronization pulses, and signal levels in the amplifiers and control circuits. Mechanical determinations insure proper sequencing and positioning of the moving parts.
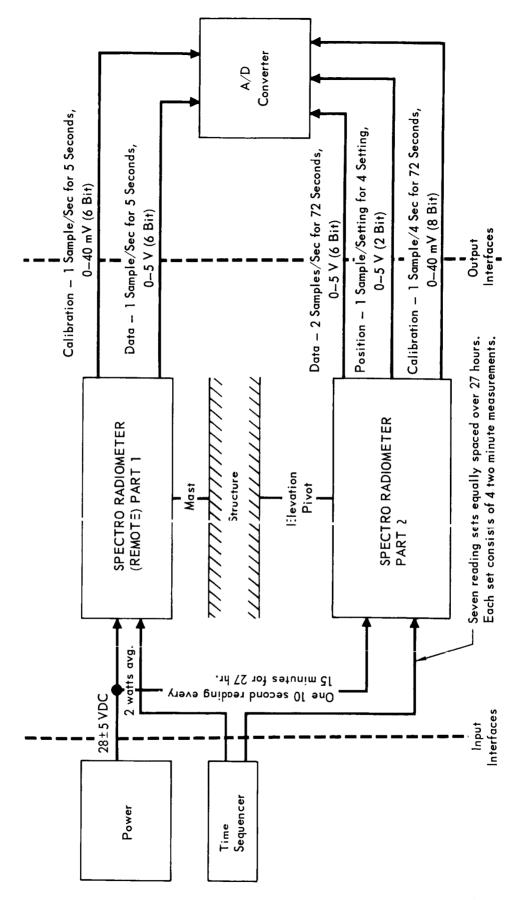
14.3-54

SPECTRO RADIOMETER INTERFACE DIAGRAM

Figure 14.3.6-3

14.3-55

Once the instrumentation has been sterilized, only electrical tests need be performed. These verify operations and are accomplished as part of the pre-launch functional checkout on the Orbiter prior to descent (when extensive handling provisions are available).

14.3.6.9 <u>Development Requirements</u> - The technology for the spectro radiometer package is available and none of the items require extensive development. The main emphasis will be directed to keeping the equipment small, simple, integrating it with the SL, and insuring its reliability.
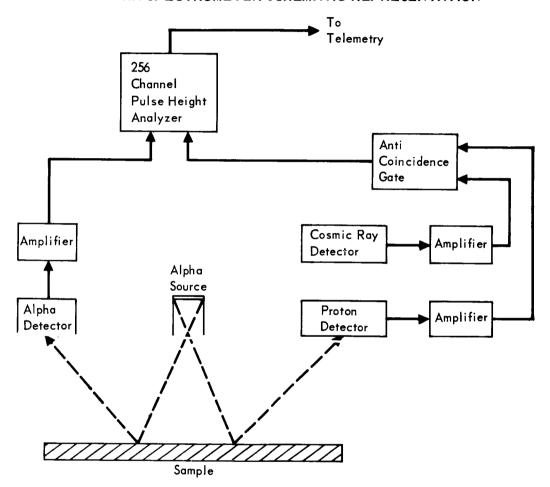
14.3.7 Alpha Spectrometer

14.3.7.1 Equipment Identification and Usage - The Alpha Spectrometer provides an elemental analysis of the surface material. It identifies the elements and their relative abundance in the surface. A schematic representation is shown in Figure 14.3.7-1. The collimated beam of monoenergetic alpha particles, from a radioisotope such as Curium -242, is directed upon the sample to be analyzed. Alpha particles which undergo a large angle backscattering have a maximum energy which is dependent upon the atomic number of the nucleus by which they were scattered. The energy spectrum from a mixed sample is made up of a series of plateaus of the type shown in Figure 14.3.7-2. The position of the drop identifies the element and the magnitude provides the abundance.

A backscattered alpha particle is detected by means of a solid state radiation detector, the output of which is proportional to the energy of the alpha particle. This output pulse is amplified and fed into a multichannel pulse height analyzer which records the number of particles in each pulse height (energy) range. The number versus energy data is the information telemetered. Many nuclei, when bombarded by alpha particles, will undergo alpha-proton (α, p) nuclear reactions. The energy of the resulting proton is characteristic of the target nucleus. The protons are detected and analyzed in the same manner as the alpha particles. The proton detectors are covered with a thin gold window which stops the backscattered alpha particles. To eliminate recording of cosmic ray protons, each proton detector is backed by an additional solid state detector. Any pulse from this cosmic ray detector will reject a coincident pulse from the proton detector. The alpha spectrometer consists of two packages, the sensor head and the electronics unit.

Sensor Head - The sensor head contains the six collimated Curium -242 (Cm^{242}) alpha sources, two alpha detectors, four proton detectors, four proton guard detectors and the head electronics. The detectors are all solid state radiation detectors and are arranged such that in the event of a failure, the malfunctioning detector can be disconnected. The Sensor head electronics contains all the electronics necessary to power the detectors, amplify the signal, reject the background radiation, discriminate against pulses out of the desired pulse height range, mix the detector signals, and convert the signals from pulse height to a time signal.

Electronics Unit - The electronics unit contains two 256 channel pulse height analyzers, 256 ten bit alpha counters (top 8 are read out), 256 8 bit proton counters, three buffer registers for temporary data storage and the readout system to feed data to the transmission system.
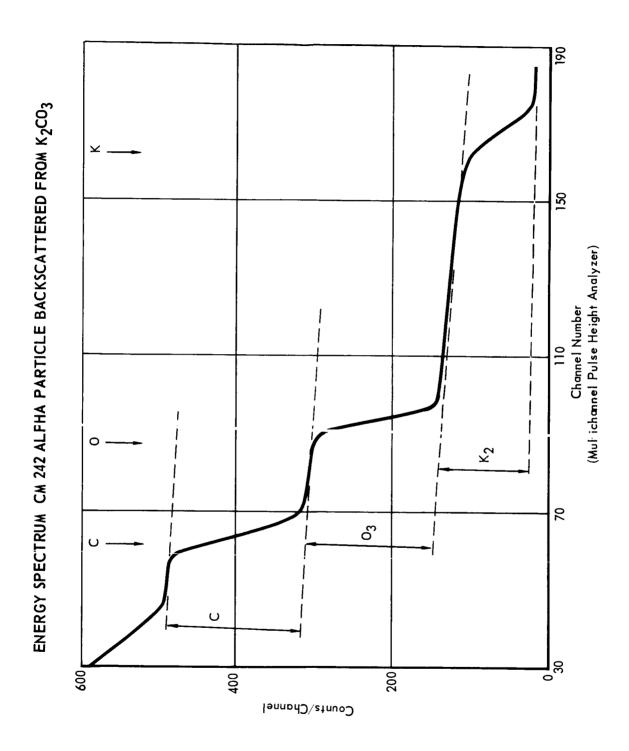
ALPHA SPECTROMETER SCHEMATIC REPRESENTATION

To
Telemetry

256
Channel
Pulse Height
Analyzer

Anti
Coincidence
Gate

Amplifier

Alpha
Source

Cosmic Ray
Detector

Amplifier

Alpha
Detector

Proton
Detector

Amplifier

Sample

ENERGY SPECTRUM CM 242 ALFHA PARTICLE BACKSCATTERED FROM K_2CO_3

Channel Number
(Mul· ichannel Pulse Height Analyzer)

Counts/Channel

14.3.7.2 <u>Design Requirements and Constraints</u> - A suitable location must be provided which will allow for the analysis of prepared samples. Sufficient insulation is required to obtain temperatures within tolerance ranges (non-operating: -50°C to + 75°C, operating: -30°C to + 50°C). The landing must be accomplished with sufficiently low contamination of the surface. If radiation levels exceed 50 mr/hr of > 0.15 MeV, gamma radiation (e.g. from radioisotope heaters) shielding must be added to reduce it to this level.

14.3.7.3 <u>Physical Characteristics</u> - The physical characteristics are summarized in Figure 14.3.7-3 . The arrangement of the sources, detectors and electronics in the sensor head is shown in Figure 14.3.7-4.

14.3.7.4 <u>Operational Description</u> - The mission sequence is shown in Figure 14.3.7-5. After touchdown the alpha spectrometer is turned on for a fifteen minute warm-up period. A two hour background count is then taken with a beryllium sample in place, which will give no backscattering. The background data is then read out, the first prepared sample is received from the sample processor and an eight hour analysis is performed. After the eight hours, the data is read out and the sample changed. The process is repeated for the second and third prepared samples. After the data for the third sample is read out, the instrument is turned off.

14.3.7.5 <u>Performance Objective</u> - The alpha spectrometer will provide information concerning the composition of the Mars surface material. The expected resolution is three atomic percent for the elements from boron to calcium, $\pm$ 1 atomic number from titanium to zinc and $\pm$ 3 atomic numbers from zinc to silver. The elements above silver are considered in groups of ten.

14.3.7.6 <u>Interface Definition</u> - An interface block diagram appears in Figure 14.3.7-6. The data output is of two main types: (1) the engineering data from sensors monitoring the operation of the instrument, and (2) the sample data which gives the energy spectra of the alpha particles and protons. The engineering data consists of two head temperatures and two voltages (7 bits each) which are read once each 15 minutes, six detector data rates (7 bits each) and six detector states (1 bit each) which are read once each ten minutes of operation. The sample data consists of 512 8 bit words per sample. For the alpha spectrum, these 8 bits are for the total count, 2^3-2^{10}.

The sensor head must be mounted so that the sample collecting and processing system can provide the prepared samples for analysis. The standard sample which is carried onboard must be capable of being repeatedly used.
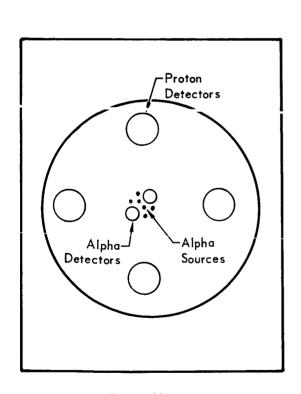
14.3-60

TABLE OF PHYSICAL CHARACTERISTICS

Volume	600 in^3
Weight	10.0 lb
Power	2 Watts
Energy	54 Watt hr
Accuracy	3 Atomic Percent Boron (5)* to Calcium (20) ± 1 Atomic Number Titanium (22) to Zinc (30) ± 3 Atomic Numbers Gallium (31) to Silver (47)

*Atomic Numbers

Figure 14.3.7-3
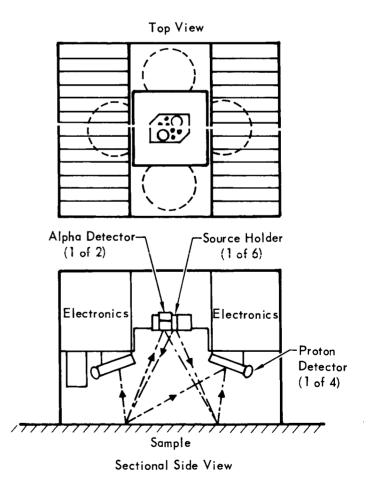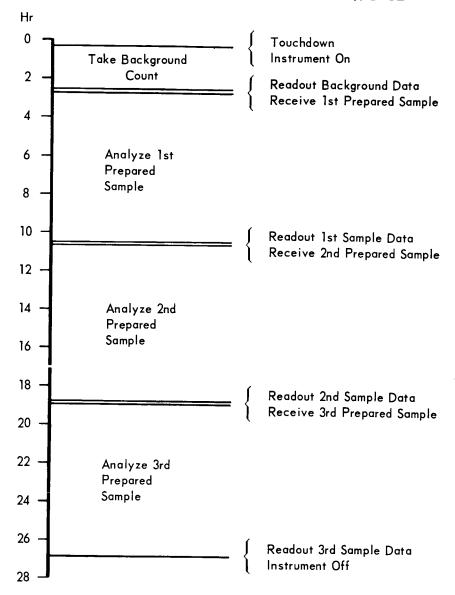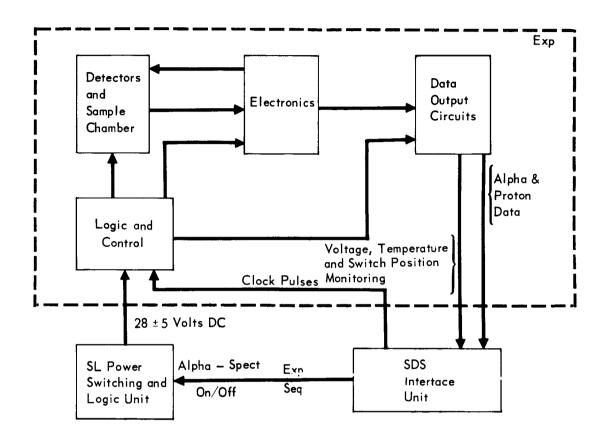
ALPHA SPECTROMETER SENSOR HEAD LAYOUT

Bottom View

Top View

Sectional Side View

Figure 14.3.7-4

14.3-61

ALPHA SPECTROMETER MISSION SEQUENCE

Figure 14.3.7–5

ALPHA – SPECTROMETER INTERFACE BLOCK DIAGRAM

14.3.7.7 <u>Reliability and Safety Considerations</u> - All the detector systems are re-
dundant and means are provided for detecting malfunctions and eliminating the mal-
functioning detector system from use. The operation of the electronics unit is
critical to the success of this experiment. Only a failure of both multichannel
analyzer systems will result in complete failure to obtain the surface composition.
A failure in the proton multichannel analyzer will degrade the results and a
failure in the alpha analyzer will seriously degrade the results of the experiment.

When handling radioisotopes there is always a safety problem. Care must be
taken in preparation and handling of the sources. The fact that the Cm^{242} sources
are easily shielded and have a relatively short half-life (163 days) greatly
reduces the dangers.

14.3.7.8 <u>Test Requirements</u> - After the instrument is mounted in the canister and
ready for launch, the engineering data will be read and a functional test will be
made with a standard sample.

Engineering data and functional test with the standard sample will be perform-
ed as in the pre-flight test and in-flight monitoring.

14.3.7.9 <u>Development Requirements</u> - The development of the 512 Counters will re-
quire considerable development effort. The remainder of the instrument is within
present state-of-the-art capabilities. Further developments in source preparation
techniques, detector design and electronics miniaturization are expected to improve
accuracy and reduce size, weight and power requirements.

14.3.8 GAS CHROMATOGRAPH

14.3.8.1 **Equipment Identification and Usage** - The gas chromatograph, Figure 14.3.8-1, will be used for the chemical analysis of the atmosphere, the subsurface atmosphere (samples provided through vent tubes in the subsurface probe), and surface material volatiles. The major components of the chromatograph are:

    a. Pyrolysis oven (two temperatures levels: 150°C and 700°C)

    b. Carrier gas supply (100 millimeters^3 helium at 5000 psi)

    c. Column oven #1 (10°C ± 1°C)

    d. Column #2 (50°C to 300°C range, 10°C/min rate;

                300°C ± 1°C for 15 min.)

    e. Carrier gas flow control (10 ± 0.1 cubic^3/min.)

    f. Sample inlet (includes a gas sample compression piston, 48/1 ratio and

                a gas sample inlet valve).

    g. Six micro thermal conductivity detectors.

    h. Four separation columns

        #1 porapak Q at 10 ± 1°C, 6' x 0.03"

        #2 5 A molecular sieve 10 ± 1°C

        #3 silicone SE - 54

            temperature 50 to 300°C at 10°C/min., 15 min. at 300°C ± 1°C

        #4 carbowax 20 M terephthalic acid reacted column, temperature programmed

            from 50 to 300°C at 10°C/min., 15 min. at 300°C ± 1°C

The gas chromatograph (GC) is a relatively simple, rugged instrument which is unexcelled for quantitative analysis of organic compounds.

The gas chromatograph can be used as a "life detection" system if a suspect material is introduced to the GC properly. If we assume a chemistry similar to that found on Earth (i.e. based on carbon, nitrogen, etc.), the positive identification of certain chemical compounds are good indications of life.

14.3.8.2 **Design Requirements and Constraints** - A requirement which resulted in the selection of the preferred pyrolysis four-column gas chromatograph is that the instrument be capable of analyzing atmospheric samples, and subsurface material volatiles obtained by heating surface samples. It is necessary to be able to detect the presence of both organic and inorganic compounds with the gas chromatograph including the measurement of the water vapor in the atmosphere. The atmospheric sample inlet should be located to minimize contamination caused by vehicle outgassing. The microthermal conductivity detectors were chosen in the

GAS CHROMATOGRAPH FUNCTIONAL BLOCK DIAGRAM
ELECTRICAL AND MECHANICAL SYSTEMS

INPUT

Soil Sample Collector

H_e Carrier Gas

Pyrolyzer (Volatilizes Soil Sample)

Pressure Regulator

Calibration Sample

Time Sequence Master Control

Power Supply and Temperature Controller

Detector Power Supply and Current Regulator

Temperature Programmer

To Detectors (1 Thru 6)

Data Output Electronics

To Science Data Subsystem

DATA OUTP

——————— Material Transfer

— — — — — Electrical Signal

············· Electrical Power

⊗ Automatic Valve

D Chromatograph Microthermal Conductivity Detector

Figure 14.3.8−1

14.3−66 −(

Subsurface Gas Samples

INPUTS

Piston

Compressor

Martian Atmospheric Gas Samples

COLUMN OVEN 1

Column No. 1 Parapak "Q"

D1

D2

Delay Line

GC Section 1

Column No. 2 5A Molecular Sieve

D3

Flow Controller

Vent Filtered Gas

Flow Controller

Vent Filtered Gas

COLUMN OVEN 2

Column No. 3

SE 54 Silicone

D4

D5

GC Section 2

Column No. 4

Tetraphthalic Acid Reacted CW20M

D6

GC Section 3

Flow Controller

Vent Filtered Gas
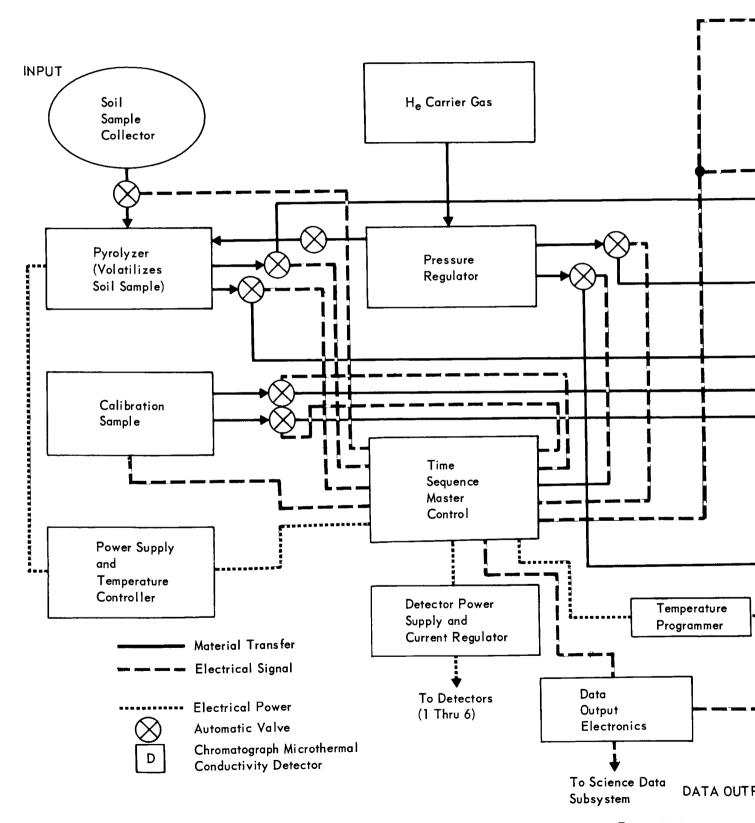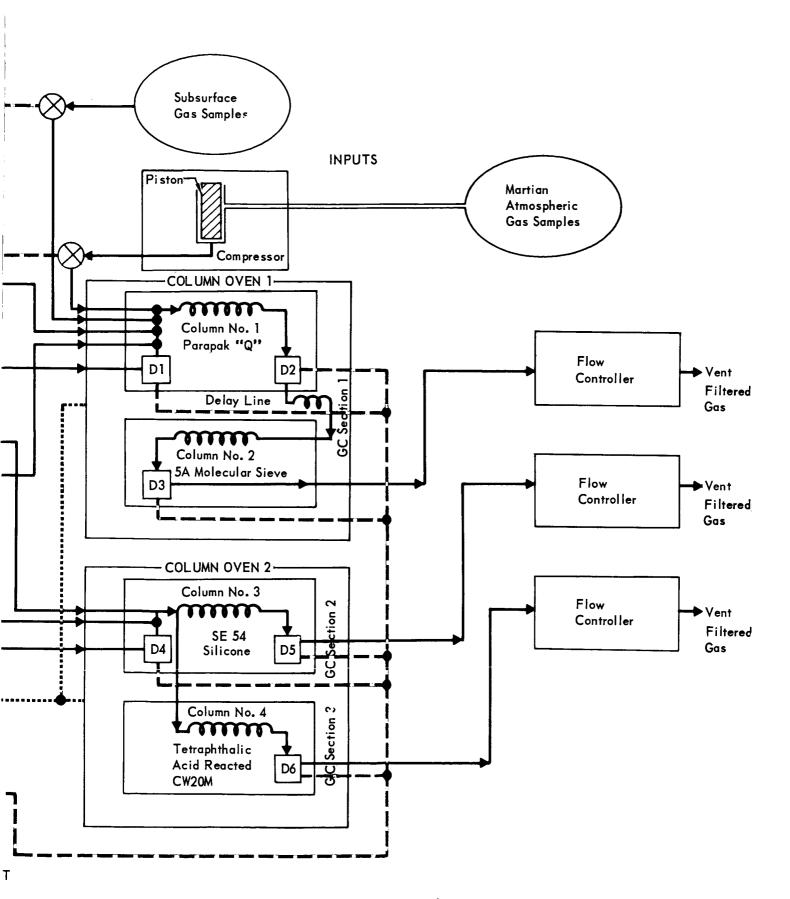
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14.3-66.2

preferred design in order to minimize the number or carrier gases required for analysis. Although a flame ionization detector is more sensitive than the thermal conductivity detector, it requires both hydrogen and oxygen. If an argon ionization detector was used, we would need different carrier gases for the atmosphere and soil analysis systems since we could not measure atmospheric argon with an argon carrier gas. However, the argon/oxygen analysis may place severe power limitations on the GC-1 column oven since it is necessary to perform this particular analysis at 10°C, while the spacecraft ambient temperature varies from 40°F to 120°F.

14.3.8.3 <u>Physical Characteristics</u> - The physical characteristics of the preferred gas chromatograph are:

    a. Weight: 15 lbs

    b. Power: 15 watts ave, 40 watts max for four five minute runs

    c. Size: 7" x 7" x 8"

    d. Data: 303.3×10^3 bits

The physical arrangement of the entire gas chromatograph system is shown in Figure 14.3.8-2.

14.3.8.4 <u>Operation Description</u> - In the gas chromatograph, volatile materials are injected into a moving carrier gas stream and separated according to preferrential interaction with a liquid and solid contained in a heated column. In a mixture of several components, each component will pass through the column at a different rate and will be observed in the output of the thermal conductivity detector at the end of the column at different times. To analyze solid surface materials, the sample is heated to drive off volatiles which are then analyzed in gas form by the gas chromatograph.

    The following is a detail description of how the chromatograph is used to analyse 1) atmosphere, 2) subsurface gas, and 3) soil volatile samples. In the chromatograph an inert stream of gas, the carrier gas, contains the unknown in the vapor phase. The gases flow through a column containing an appropriate interaction phase on a solid support and by a process of selective interaction the various components of the unknown are spread out along the column. Eventually they are swept out of the column at different times. The time of elution multiplied by the gas flow rate is characteristic of particular species, and is called the "retention volume", V_R. Many different types of columns exist but they can usually be divided into two classes (1) gas solid and (2) gas liquid columns. In the former, the unknown interacts with the column material by a process of selective

14.3-67

GAS CHROMATOGRAPH FUNCTIONAL LOCATION LAYOUT

To Spacecraft Mode Selector & Power On & Off

Spacecraft Harness Connector Snap 15 watts min. To 40 watts max.

Test Connector

Helium Carrier Gas Bottle

Pressure Regulator

Soil Sample Collector Tube to Pyrolyzer

Gas Probe for Atmospheric Sample & Subsoil Gases

Flow Controller

Detector Power & Supply

Data Electronics & Time Sequence Master Control

Temperature Controller for Pyrolyzer

Temperature Programmer for GC No. 2 & 3

Calibrated Sample Container

No. 1

No. 2

No. 3

Vents or Outlet Gas Scrubbers

Atmospheric Gas Sample Compression Valve

Automatic Material Transfer Valves

GC No. 1

Pyrolyzer Gold Mold 150°C ± 1° C & 700°C ± 2° C

Inlet Sample Splitter

GC No. 2

GC No. 3

Detectors

Insulation

Insulation

Figure 14.3.8-2
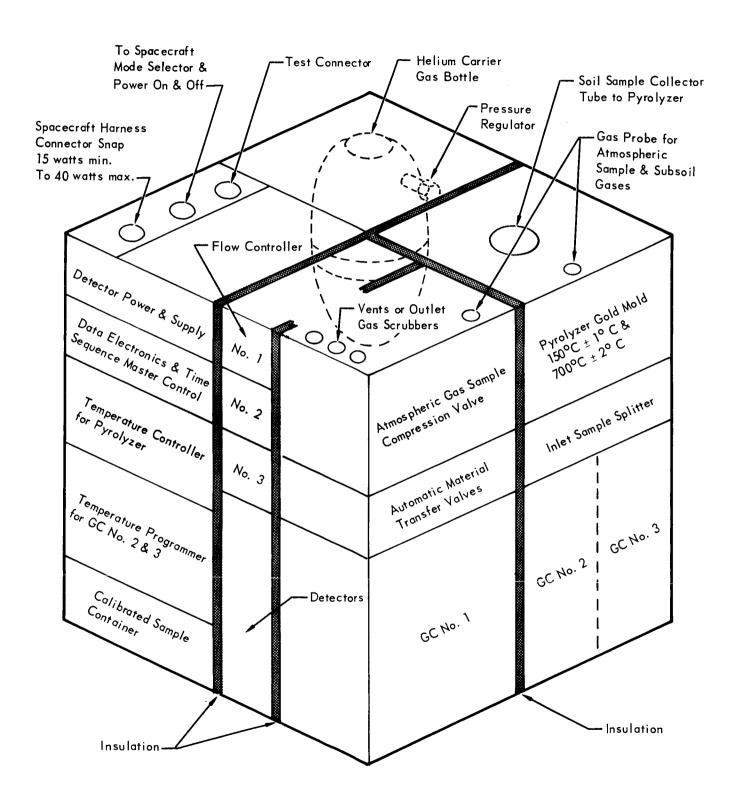
14.3-68

absorption and description. In gas-liquid chromatography, the separation is performed by preferential solubility of each component down the length of the column. The pressure of the unknown in the vapor above the liquid phase is proportional to the amount dissolved in the liquid (Raoult's Law) and moving gas "pushes" the material through the column at different rates, thereby effecting separation. Columns can also be subdivided according to the method by which the liquid or solid phase is dispersed: in capillary columns the organic coats a solid which is "packed" into the column; and coated open tubular columns which combine the advantages found in both packed and capillary columns.

It is necessary to use different column materials for different classes of chemical compounds. That is, a column such as a molecular sieve is an excellant column for separating the so called permanent gases (O_2, N_2, H_2, CO_2, CH_4) but is useless for separating other hydrocarbons. Similarly a good column for hyrocarbons is useless for separating amines. For complete analysis a system utilizing several columns is necessary.

It is important to remember that gas chromatography is ONLY a means for separation. Identification of each and every component is a separate and necessary job. This can be accomplished by:

a. Separation of each material at the outlet and then analysis by either a chemical or physical method.

b. Known can be injected into the system and the retention volume of the unknown compared with that of the known. It is usually necessary to perform this type of identification with several different columns at several different temperatures.

The temperature of the column effects the rate at which the unknowns are eluted. That is, low molecular weight compounds pass through the column at low temperatures. They are not separated at high temperatures since they all emerge in a few seconds and can not be resolved. Therefore; if the mixture contains both low and high molecular weight materials it becomes desirable to steadily increase the column column temperature during analysis. This is called "temperature programming" and is an extremely powerful separation procedure.

In addition to the separation columns the basic components of a gas chromatograph are: the sample inlet system, the carrier gas and associated pressure and flow regulators, the detector (one or more), and the data readout system. The mission operation sequence for the three analyses discussed in the following paragraphs appears in Figure 14.3.8-3.
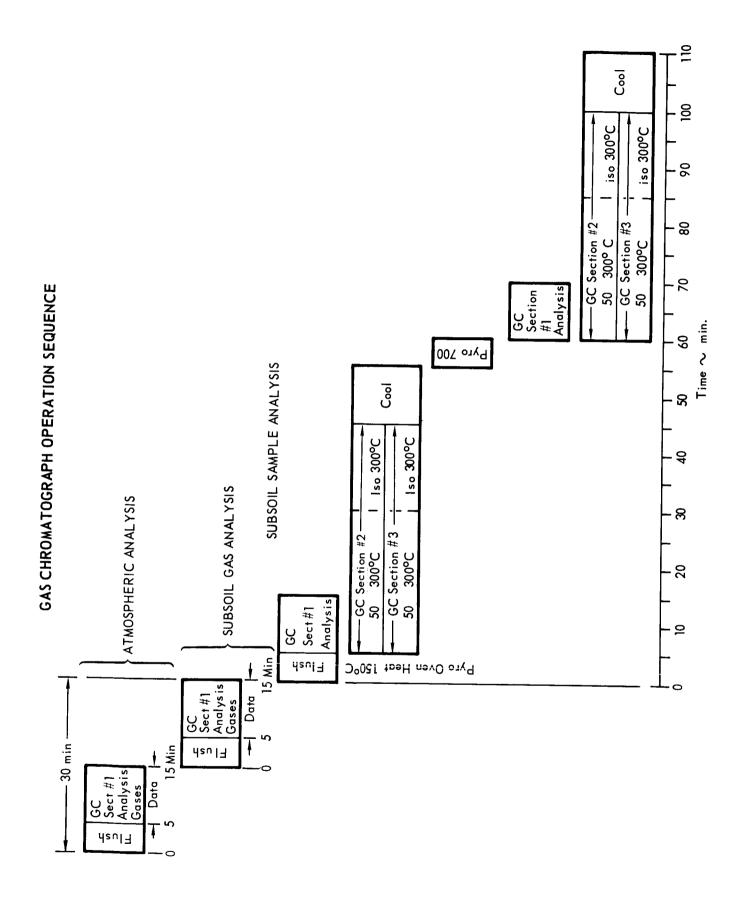
GAS CHROMATOGRAPH OPERATION SEQUENCE

Figure 14.3.8-3

o <u>Atmospheric Analysis</u> - It is desirable to analyze the Martian atmosphere for the following gases: carbon dioxide, carbon monoxide, argon, nitrogen, oxygen, methane, and water vapor. The detection of these gases can best be accomplished with a microthermal conductivity detector. The minimum detectable mass in this type of detector is approximately 0.01 gram. Therefore, we must introduce a volume of gas sufficiently large to contain at least 0.01 gram of each material in question. If we use a 12 ml sample of the atmosphere at the partial pressures listed, the following mass of each component would be present:

Mass of Each Component in a Selected Martian Atmosphere

	partial pressure	component mass
Carbon Dioxide	4 torr	106 grams
Argon	0.1	2.4
Nitrogen	0.1	1.7
Oxygen	.01	.19
Carbon Monoxide	.01	.19
Methane	.001	.01
Water	.001	.01

However, it is not practical to introduce the gas from a 12 ml inlet volume. The gas must be compressed to a volume no greater than 0.25 ml. This requires a compression factor of 48 in the inlet valve prior to admittance in the gas chromatograph. This is a simple operation but it is necessary that the valve be constructed so that the dead volume in the inlet system be less than 25 microliters.

The separation of the seven components requires a system containing three thermal conductivity detectors, an inlet valve, a porapak column controlled at $10 \pm 1°C$, a gas delay line and a second column of 5 molecular sieve cooled to $10° \pm 1°C$. A block diagram of this system appears in Figure 14.3.8-4. The three detectors are necessary to provide a reference (detector 1) and a detector for the outlet of each column. The first column is 6 feet by 0.030 inch internal/diameter packed with porapak "Q" which groups the argon, oxygen, and nitrogen into one peak and separates the methane, carbon monoxide, carbon dioxide and water in the order listed. The composite $Ar-N_2-O_2$ enters a delay line (approximately 4 feet of capillary tubing)while the CH_4, CO and CO_2 are recorded in the second detector. The Ar, O_2, and N_2 are resolved with the molecular sieve column while the H_2O is still passing through the porapack column. Then the H_2O emerges and is recorded. A total of 8 peaks are recorded, They are, in order, the composite $Ar-O_2-N_2$, CH_4, CO_2 (all recorded in detector 2), then N_2, O_2 and Ar in detector 3, and finally

14.3-71

GAS CHROMATOGRAPH SCHEMATIC BLOCK DIAGRAM
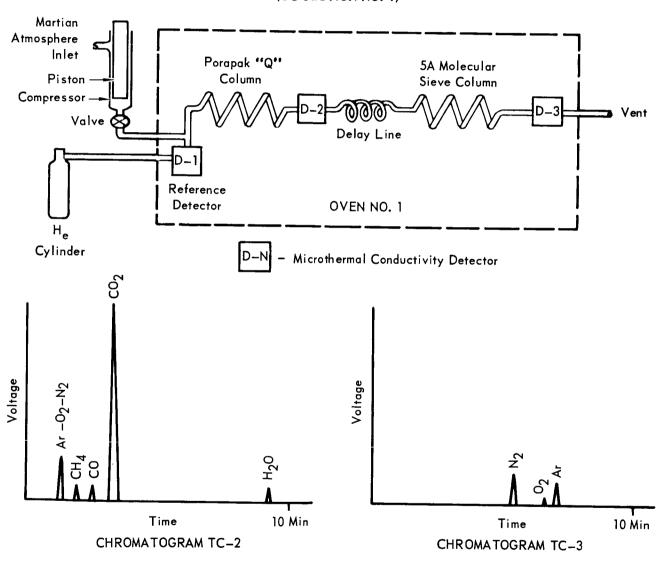## ATMOSPHERIC ANALYZER
(GC SECTION NO. 1)

CHROMATOGRAM TC-2

CHROMATOGRAM TC-3

H_2O in detector 2. The entire analysis requires approximately 10 minutes with a helium flow rate of 10 ml/min. The chromatograms from each detector are shown in Figure 14.3.8-4. To insure proper operation, a 0.25 cc calibration mixture containing Ar, O_2, N_2, CO, CO_2, CH_4, and H_2O will be run following the actual Martian gas and soil volatile analysis. An initial calibration will be carried out and the calibration sample collected at the vent to avoid atmospheric contamination.

<u>Subsurface Gas Analysis</u> - The analysis of the subsurface gases is essentially identical to that of the atmospheric gases. However, the gases must be collected with a deployable probe and then admitted to the gas chromatograph.

° <u>Subsurface Sample Analysis</u> - It is essential that the Martian soil be treated prior to admittance into the gas chromatograph. The simplest most reproducible technique consists of pyrolyzing the sample in a high temperature oven at a controlled rate. The product gases will be passed through three different chromatographic columns (molecular sieve, polar, and non-polar) connected in parallel into microthermal conductivity detectors. The gas output from the detector is passed through a flow controller. Thus, the entire system consists of a sample introduction device, a pyrolysis oven, a well regulated carrier gas, and a gas chromatograph. Refer to Figure 14.3.8-1. The entire operation is as follows:

a. Sample System: An 0.2 cm^3 finely ground sample (particle size 100 - 150 micron) is introduced into the pyrolysis oven. The system provides for the introduction of a second sample volume, 0.2 cm^3 in case the initial sample produces copious amounts of volatiles which saturate the chromatograph system.

b. Pyrolysis Oven: The sample in the heating oven is first flushed with the carrier gas, then heated to 150°C for 5 minutes to remove any low molecular weight organic compounds. This gaseous material is then admitted to the chromatograph for analysis. The oven is rapidly heated to 700°C and held at this temperature for five minutes after which time the gaseous portion is admitted to the GC for analysis. The maximum power required for this operation is 40 watts. The 150°C heating will require about 10 watts for five minutes and the entire 40 watts will also be needed for five minutes.

c. Gas Chromatograph: The chromatograph system contains the high pressure He cylinder, automatic valves and switching arrangement, three columns, 6 detectors, temperature programmed oven, and flow controllers. The high pressure cylinder contains 10 liters of helium at a pressure of 7000 psi and weighs 0.7 pounds. The

pressure valves must control the pressure across the GC column to 40 $\pm$ 1 psi and regulate the flow to 10 $\pm$ 1 ml/min. The automatic inlet valves are programmed to open and close at the appropriate time and the vapor above the heated soil is forced into the GC where it is split into 3 separate fractions.

In GC-1 the product gases are analyzed for N_2, O_2, CO, CO_2 and H_2O produced during heating. The column in GC-2 is non-polar, such as SE-54 silicon, while a polar column, carbonwax 20M terephthalic acid, is used in GC-3. The columns in GC-2 and GC-3 are temperature programmed from 50° to 300°C (at a rate of 10°C per minute) and controlled isothermally at 300°C for an additional 15 minutes. The temperature must be controlled to within one-half degree. The effluents from the columns are monitored separately by individual micro thermal conductivity detectors. The analysis occurs simultaneously in all theee columns. In each case the detection system consits of a part of detectors forming two arms of a Wheatstone bridge. The current through each element is 15 milliamps at 12 volts. Reference detectors are required, however a single detector serves as the reference for GC-2 and GC-3 and another is needed for GC-1.

All detectors are contained inside the oven containing the column. The output consists of current peaks (up to 25) whose amplitude is several nanoamps and whose time width is 10 - 60 seconds. The quantities of interest are the time it takes for the peak to reach its maximum height (emergent time) and the total area of the peak. These two quantities should be determine to an accuracy of 2%. If the detector current becomes greater than 1 milliamp, the smaller (0.025 g) pyrolysis system must be used.

The analysis time, power consumption and data requirements for the atmosphere, sub-soil gas, and 4 soil analyses are shown in Figure 14.3.8-5. The times shown in this figure correspond to the science sequence for a morning landing and are related to the time of touchdown.

14.3.8.5 <u>Performance Characteristics</u> - The selected gas chromatograph will have the following performance characteristics:

Accuracy:	2% for major components
Range:	Detects compounds with molecular weight through 300.
Sensitivity:	Organic materials in the soil, 10 parts/million
	Inorganic gases 0.001 torr.
Pyrolysis Temperatures:	150°C and 700°C

GAS CLOMATOGRAPHY EXPERIMENT
SEQUENCE REQUIREMENTS

Mission: (1) 8 Atmospheric Analyses (2) 8 Subsoil Gas Analyses (3) 4 Subsoil Analyses	Total Operation Time = 15.2 hrs.	Total Energy = 236 watt-hrs	Data 303.3 x 10^3 Bits
Event Sequence	Time for Each Event	Power for Each Event	Data Bits
Helium & Column Temperature ON	30 minutes	15 watts	
Std. Calibration Sample CG Columns 1, 2, 3, & 4	50 minutes		19.2 x 10^3
Atmosphere & Subsoil Gases	30 minutes		12.8 x 10^3
Soil Volatile Analysis	110 minutes	40 watts 5 minutes / 15 watts	38.4 x 10^3
Soil Volatile Analysis	110 minutes	40 watts 5 minutes / 15 watts	38.4 x 10^3
		Off	
Standby	30 minutes		
Atmospherie & Subsoil Gases	30 minutes	15 watts	12.8 x 10^3
Atmospherie & Subsoil Gases	30 minutes		12.8 x 10^3
Atmospherie & Subsoil Gases	30 minutes		12.8 x 10^3
		Off	
Standby	30 minutes	15 watts	
Soil Volatile Analysis	110 minutes	40 watts 5 minutes / 15 watts	38.4 x 10^3
Atmospherie & Subsoil Gases	30 minutes		12.8 x 10^3
		Off	
Standby	30 minutes	15 watts	
Soil Volatile Analysis	110 minutes	40 watts 5 minutes	38.4 x 10^3
Atmospherie & Subsoil Gases	30 minutes	15 watts	12.8 x 10^3
Atmospherie & Subsoil Gases	30 minutes		12.8 x 10^3
Atmospherie & Subsoil Gases	30 minutes		12.8 x 10^3
Std. Calibration Sample CG Columns 1,2,3, & 4	50 minutes		19.2 x 10^3

Time From Touchdown (Hours): 0–29

294.4

Monitoring Data 7 bits/hr x 15.2 hrs.   8.9 x 10^3 bits

Total Data 303.3 x 10^3 bits

Figure 14.3.8–5

14.3–75

Oven temperature accuracy: ± 1°C
     Expected number of detected components:

          atmosphere: 1 to 10

          soil: 1 to 25

14.3.8.6 <u>Interface Definition</u> - The gas chromatograph is not a deployable instru-
ment and the samples must be supplied to the instrument. This requires an active
interface with the atmosphere, a subsurface probe, and with the soil gathering
mechanism.

     Soil sample size provided by the sample processor 1 cm^3/batch

                                                         4 cm^3/ total

     Power consumption: 15 watts ave

                                                         40 watts max for four

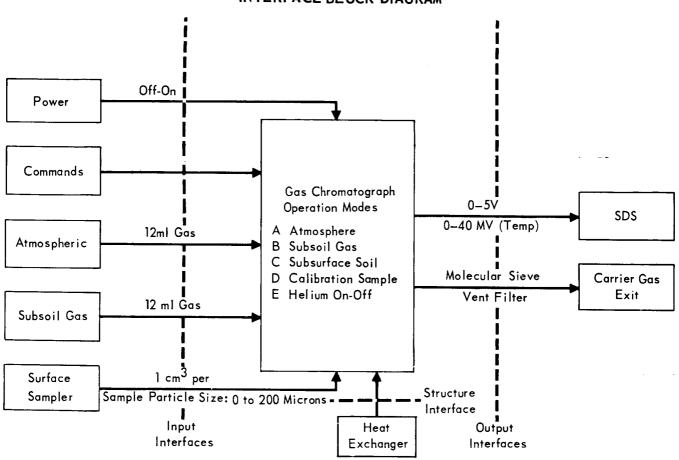   five minute runs

     Energy: 236 watt hrs

     Thermal environment during operation after landing 40° to 120°F

     Total Data Output: 303 x 10^3 bits

A block diagram illustrating the interfacing of the gas chromatograph with the
Science Payload is shown in Figure 14.3.8-6 and the electronic interface summary
appears in Figure 14.3.8-7.

     The data for the soil analysis is the sum of two (one run for a 150°C
pyrolysis temperature plus a second run for a 700°C pyrolysis temperature) 3200
bit analysis for the soil volatiles using the same two columns as used for the
atmospheric analysis. In addition, 25,600 bits are utilized for the analysis of
the soil volatiles using the third and fourth columns. The 25,600 bits result
from an analysis time of 40 minutes, a sample rate of one per 6 seconds, the use
of two detectors, two amplifiers (low range and high range), and two pyrolysis
temperatures: (2 amplifiers) x (40 x 60 seconds) x (1/6 sample/second) x (8 bits/
sample) x (2 detectors) x (2 temperatures) = 25,600 bits. The total data per soil
analysis is thus 25,600 plus two times 6400 which equals 38,400 bits and the
analysis time is 100 minutes (50 minutes for analyzing the 150°C pyrolysis pro-
ducts and 50 minutes for analyzing the 700°C pyrolysis products). An additional
10 minutes is required for cooling the columns and flushing, which results in the
total time of 110 minutes for the soil analysis listed in Figure 14.3.8-3, and
Figure 14.3.8-5.

     The data for the atmospheric and subsoil gas analysis is equal to the data
rate, (one sample per three seconds) times the number of bits per sample (8),

14.3-76

GAS CHROMATOGRAPH
INTERFACE BLOCK DIAGRAM

Power — Off-On → Gas Chromatograph Operation Modes

Commands →

Atmospheric — 12ml Gas →

Subsoil Gas — 12 ml Gas →

Surface Sampler — 1 cm^3 per

Sample Particle Size: 0 to 200 Microns

Gas Chromatograph
Operation Modes

A Atmosphere
B Subsoil Gas
C Subsurface Soil
D Calibration Sample
E Helium On-Off

0–5V
0–40 MV (Temp) → SDS

Molecular Sieve
Vent Filter → Carrier Gas Exit

Structure Interface

Heat Exchanger

Input Interfaces

Output Interfaces

Figure 14.3.8–6

14.3–77

ELECTRONIC INTERFACE – SUMMARY
EXPERIMENT: GAS ANALYSIS
(GAS CHROMATOGRAPH)

1. Operating Modes

MODE	MODE CHARACTERISTICS	SCIENCE PARAMETER SAMPLE RATE
Atmos – Subsurface Gas Analysis	• Eight – 20 minute analyses, three each at sunrise and sunset, one at noon and one at midnight. Subsurface 10 minute Cols 1 and 2 parallel operation then atmos 10 minute Cols 1 and 2 parallel operation	One/3 seconds
Soil Volatiles Analysis	• 4 – 10 minute analyses phased with soil sampler operation. Temp 1 – 10 min Cols 1 and 2 in parallel then 40 min Cols 3 and 4 in parallel, then cool 10 min. Repeat for Temp 2.	One/6 secs(Cols 3 & 4) One/3 secs(Cols 1 & 2)
Calibration	• Two operations (Before and after use) 50 minutes each – Cols 1 and 2 in parallel (10 min) and Cols 3 & 4 in parallel (40 min).	"

2. Science Data Characteristics

PARAMETER	FORM	ACCURACY	REMARKS
Col 1 Hi Sens	0–5V	8 Bit	Used for Atmos & Subsurface Gas – 6400 Bits per 10 Min Analysis
Col 1 Lo Sens	0–5V	8 Bit	
Col 2 Hi Sens	0–5V	8 Bit	
Col 2 Lo Sens	0–5V	8 Bit	
Col 3 Hi Sens	0–5V	8 Bit	Used for Soil Analysis 38,400 Bits per 110 Min Analysis (Two Temps).
Col 3 Lo Sens	0–5V	8 Bit	
Col 4 Hi Sens	0–5V	8 Bit	
Col 4 Lo Sens	0–5V	8 Bit	
Col 1 Temp	0–40 MV	8 Bit	One Sample/Two Minutes
Col 2 Temp	0–40 MV	8 Bit	One Sample/Two Minutes
Col 3 Temp	0–40 MV	8 Bit	One Sample/10 Minutes — During Use Only
Col 4 Temp	0–40 MV	8 Bit	One Sample/10 Minutes
Oven Temp	0–40 MV	8 Bit	One Sample/50 Minutes

3. Engineering Data Characteristics

PARAMETER	FORM	ACCURACY	SAMPLE RATE	REMARKS
Carrier Gas Press	0–40 MV	7 Bits	One/Hour	
Calib Gas Press	0–40 MV	7 Bits	One/Hour	

4. Command and Sequencing Summary

COMMAND	TYPE	MAXIMUM NRT DELAY & TOLERANCE	MAXIMUM PROPORTIONAL VALUE & TOLERANCE	MODE/TIME OF OCCURRENCE
Power On	D–NRT–R & NR	30 n ± 1m		Upon Sample Ready
Power Off	D–NRT–R & NR	1m ± 1m		After Completion
Mode	D–NRT–R & NR	30 n ± 1m	5 Values	Signal*

*See Status Commands

5. Status Commands

COMMAND	FUNCTION
Analysis Complete	For Sequencing.

6. Power Summary

OPERATION	AVERAGE POWER	VOLTAGE + REGULATION	PEAK POWER	DURATION OF OPERATION
Gas Analysis	15 W	28 ± 5 vdc	30 W	15.2 Hours
Oven Heating	40 W	28 ± 5 vdc	40 W	20 Min.

Figure 14.3.8–7

14.3–78

times the analysis time of 1200 seconds (600 seconds for the atmospheric plus 600 seconds for the subsurface gas analysis) times the number of detectors (2). The data per analysis is thus: (2 amplifiers) x (1/3 sample/second) x (8 bits/sample) x (600 seconds) x (2 detectors) = 6400 bits for each 10 minute analysis. Two 5 minute flushes in addition to the 20 minute analysis of gas samples in required which results in the 30 minute operation time shown in Figure 14.3.8-3. A total of 38,400 bits are used in a 110 minute soil analysis.

14.3.8.7 <u>Reliability and Safety</u> - Since there are a large number of valves and a complex sequencing for the gas chromatograph, this unit is expected to present a major reliability problem. The reliability of this instrument is however, expected to be better than the 0.85 allocated to all the instruments. The major safety consideration is the sterilization heating of the pressurized gas supplies.

14.3.8.8 <u>Test Requirements</u> -Calibration gas is provided for carrying out operational test of the gas chromatograph following sterilization. In flight monitoring includes the pressures of the calibration sample supply and the helium carrier gas supply.

14.3.8.9, - <u>Development Requirements</u> - The basic principles of chromatograph are well known, however the specific equipment to perform the analysis must be developed. In particular, additional work is needed on the development of pyrolysis techniques, in interpretation of programs, in data compression and handling, and in valving, detection, and calibration sample collection.

14.3.9 <u>Life Detectors</u> - Three simple culture type life detectors selected for the baseline design are: two Gulliver type life detectors which include four <u>in situ</u> probes, and a Wolf Trap life detector. Only the Wolf Trap and the <u>in situ</u> component of one of the Gulliver detectors has been developed to VOYAGER requirements. None of the many other possible instruments have been developed consistent with the present 1973 mission constraints. Therefore, in order to develop the necessary detector interface and design requirements for Phase B compliance, certain liberties have been taken with the extrapolation of Gulliver concepts and with the modification of the Wolf Trap into two 1973 surface laboratory experiment packages (two packages - three specific Life Detectors).

14.3.9.1 <u>Equipment Identification and Usage</u> - Collectively the three detectors probe for a wide variety of earth-like microorganisms through stimulated performance as measured directly from growing cultures. These detectors, through programmable conditioned measurements, provide for both the functional evaluation of life and for a preliminary estimate of its gross characteristics. Such measurements require that specific influences (experimental treatments) be brought to bear on the specimen which will predictably activate, accelerate, inhibit or inactivate the specimen to produce a response if life is present. The selected treatments should reflect the most recent data pertinent to physical, physical-chemical, chemical and microbiological properties of Martian or other extraterrestrial like soils. To this end, the assumed baseline design does reflect provision for the later selections of specific experimental treatment.

Gulliver Detector #1 probes for life at the molecular level by attempting to elicit metabolism of prepared substrates. Several variations of nutrient media (each milieu as broadly nonselective as possible) containing labeled substrates of C^{14} and/or S^{35} in aqueous solution are offered one at a time to equal portions of processed soil sample. The choice of labeled organics is predicated upon the widespread importance of the Krebs cycle in aerobic metabolism and of the Embden Meyerhof pathway in anaerobic metabolism. Viable cells, if present, assimilating one or more of the labeled substrates are likely to evolve radioactive gases when these substrates are oxidatively metabolized. The evolved radioactive gases, $C^{14}O_2$ and/or H_2S^{35}, are collected (chemadsorptively fixed) on LiOH monolayers above each culture chamber. Disintegrations from the collected gas(es) leading to β emmision (above say 35 Kev) are sensed by Geiger tubes. The disintegration rate is a measure of the net amount of gas collected and thus, is a measure of the net amount of substrate metabolized or degraded. The results may be biological or non-biological

14.3-80

in origin (as an example, reaction by soil organics which may or may not be associated with indigenous microorganisms). Since suitable control design allows differentiating between these two causes, the data returned permits a decision of either no detectable metabolic involvement of carbon and sulfur, detectable involvement but without growth or detectable involvement with growth (reproduction).

Gulliver detector #2 follows the same pattern as detector #1 except that the labeled substrates would be molecular $C^{14}O_2$ and/or H_2S^{35}, the nutient media then being that of the organism's own natural environment. In addition, sample treatment includes separation of light from dark induced fixation of the labeled gas(es). Strict phototrophs, for example, would be expected to fix $C^{14}O_2$ in the light and then when placed in the dark consume the energy compounds recently photosynthesized, thereby expiring $C^{14}O_2$ for collection. As correlates between the two detectors, the baseline design provides for: light/dark modulation of detector #1 chambers with graduated heating to combustion with oxygen in four (4) detector #2 chambers. The latter allows the differentiation of biological from non-biological gas fixing processes (both light and/or dark induced) characteristic of the sample in toto (the sum of both biological and non-biological fixation).

The Wolf Trap, detector #3, probes for life at the level of the viable entity rather than at the molecular level. The primary variable sensed is light scatter produced by a suspension of microorganism sized particles. A secondary variable sensed, that of a correlate to growth processes in aqueous culture media, is the change in hydrogen ion activity (pH) of that media. This detector in its present state of development (under Wolf Vishniac at Rochester University) displays, for E. coli a sensitivity in organisms/ml/mv of about 2 to 5 x 10^4 (the tests cited for this figure began with the inoculation of 2 to 5 E. coli and were terminated some 10 hours later, at which time the turbidity of the culture had reached about 1% of full scale above noise; 4 hours had been allowed for sterile media particles to settle prior to inoculation with the previously prepared culture).

Culture Chamber Component of Life Detectors #1 and #2 - The functional organization of the major elements comprising the integrated package (detectors #1 and #2) is shown by Figures 14.3.9-1, and 14.3.9-2. The principal detector element is the test or culture chamber (in situ test chambers are considered separately under the heading of in situ projectable module). A typical chamber and its supporting elements are shown in Figure 14.3.9-3. An aliquot of soil sample is delivered from the rotating assembly to a spring loaded delivery tube, open at its top and located in the chamber cylinder wall. Nutrient media and antimetabolite in glass ampules

THREE SPECIFIC LIFE DETECTORS
LIFE DETECTOR FUNCTIONAL BLOCK DIAGRAM

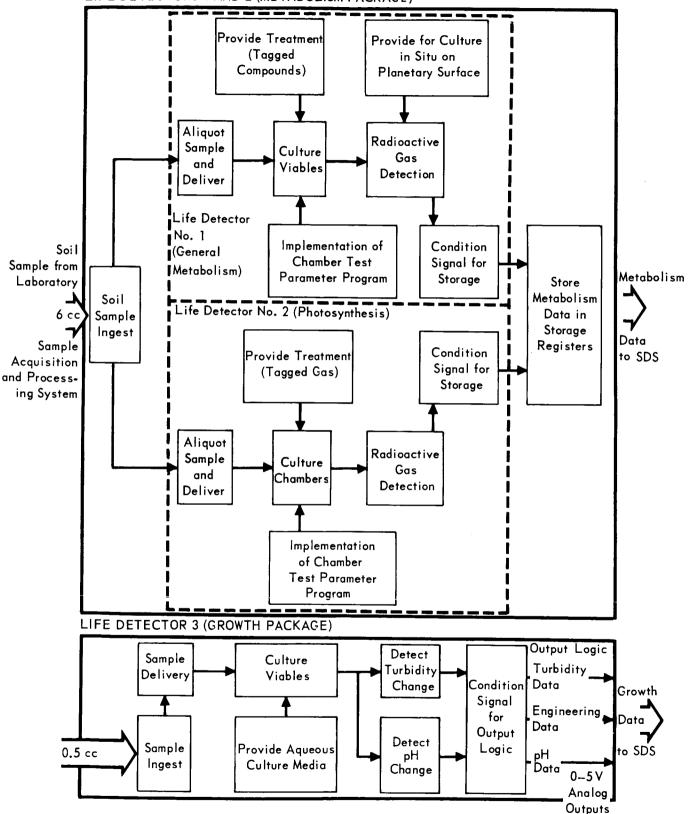LIFE DETECTORS 1 AND 2 (METABOLISM PACKAGE)

LIFE DETECTOR 3 (GROWTH PACKAGE)
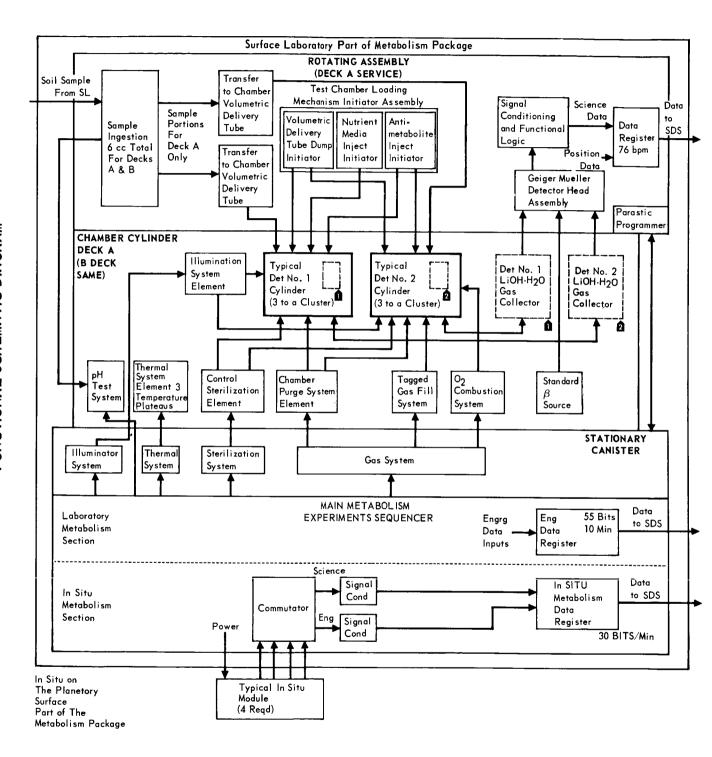

Figure 14.3.9-1

14.3-82

LIFE DETECTORS 1 AND 2 FUNCTIONAL SCHEMATIC DIAGRAM

Surface Laboratory Part of Metabolism Package

ROTATING ASSEMBLY
(DECK A SERVICE)

Soil Sample From SL

Sample Ingestion 6 cc Total For Decks A & B

Sample Portions For Deck A Only

Transfer to Chamber Volumetric Delivery Tube

Transfer to Chamber Volumetric Delivery Tube

Test Chamber Loading Mechanism Initiator Assembly

| Volumetric Delivery Tube Dump Initiator | Nutrient Media Inject Initiator | Anti-metabolite Inject Initiator |

Signal Conditioning and Functional Logic

Science Data

Data Register 76 bpm

Data to SDS

Position Data

Geiger Mueller Detector Head Assembly

Parastic Programmer

CHAMBER CYLINDER DECK A (B DECK SAME)

Illumination System Element

Typical Det No. 1 Cylinder (3 to a Cluster) ❶

Typical Det No. 2 Cylinder (3 to a Cluster) ❷

Det No. 1 LiOH·H₂O Gas Collector ❶

Det No. 2 LiOH·H₂O Gas Collector ❷

pH Test System

Thermal System Element 3 Temperature Plateaus

Control Sterilization Element

Chamber Purge System Element

Tagged Gas Fill System

O₂ Combustion System

Standard β Source

STATIONARY CANISTER

Illuminator System

Thermal System

Sterilization System

Gas System

Laboratory Metabolism Section

MAIN METABOLISM EXPERIMENTS SEQUENCER

Engrg Data Inputs

Eng Data Register 55 Bits 10 Min

Data to SDS

In Situ Metabolism Section

Science

Commutator

Power

Signal Cond

Eng Signal Cond

In SITU Metabolism Data Register

Data to SDS

30 BITS/Min

In Situ on The Planetory Surface Part of The Metabolism Package

Typical In Situ Module (4 Reqd)

Figure 14.3.9–2

14.3–83

TYPICAL TEST (CULTURE) CHAMBER CYLINDER
(SECTIONAL VIEW)

Spring Loaded
Delivery Mechanisms
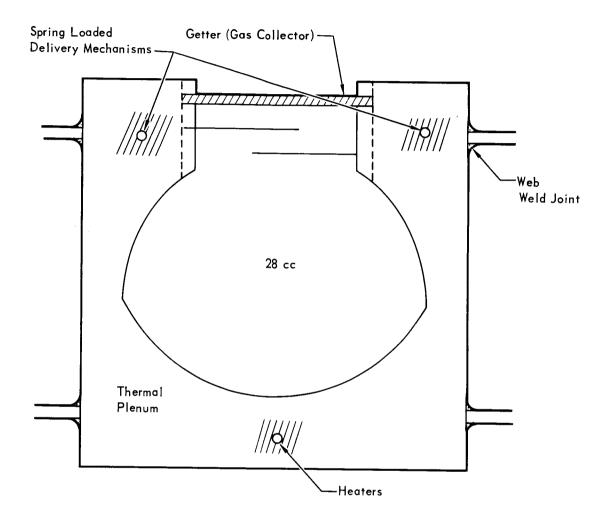
Getter (Gas Collector)

28 cc

Web
Weld Joint

Thermal
Plenum

Heaters

are also contained in the chamber cylinder. Delivery is by means of spring loaded plungers, which like the sample delivery plunger is tripped, at the proper time, by wiping its attached spoke into a milled slot in the chamber cylinder. A mechanism located in the rotating assembly provides the mechanical motivation for these functions.

Rotating Assembly Component of Life Detectors #1 and #2 - The rotating assembly, shown in Figures 14.3.9-4 and 14.3.9-5, houses the detector electronics, parasitic experiment programmer, science data registers (the latter three elements are shown in Figure 14.3.9-5) and the internal soil sample processing and delivery elements.
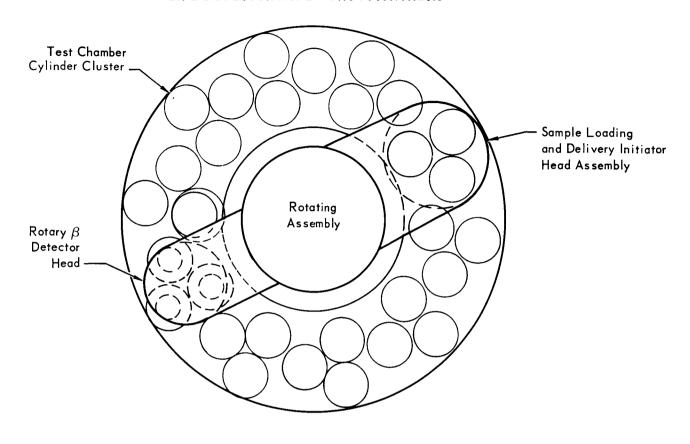
Stationary Canister Component of Life Detectors #1 and #2 - The stationary canister (Figure 14.3.9-4) contains the main detector sequencer, most of the engineering functional elements, the in situ metabolism programmer and other functional elements supporting the deployed modules (Figure 14.3.9-6). The canister also represents all but three of the SLS Life Detector package interfaces (those not represented are the soil sample acquisition system/rotating assembly interface, the SL in situ module deployment device/in situ module interface and the SL/detector package field joint).

In Situ Projectable Module Component of Life Detector #1 - Each of the four modules provided is deployed directly onto the planet's surface for its sample. The module's entire operating time is spent covering the section of soil over which it came to rest after deployment. One module is deployed in each of the four Lander quadrants. Daylight deployment is required. A modified Hazleton Mark IV Gulliver (modified by extending its length to three inches for the purpose of adding a soil/gas exchange or background radiation detector as shown in Figure 14.3.9-7) serves as the assumed baseline design for each of the four modules.

Culture Chamber Component of Life Detector #3 - Five culture cells are used in the baseline design and are shown in Figure 14.3.9-8 (shown in relation to the manifold assembly). Each cell functions both as a thermally controlled incubation chamber and as a nephelometer cuvette.

Electro-Optical Component of Life Detector #3 - The turbidity detector (nephelometer) is an electro-optical device which provides an electrical signal when light passing through the liquid in the culture cell is scattered by the small particles contained

14.3-85

INTEGRATED METABOLISM PACKAGE
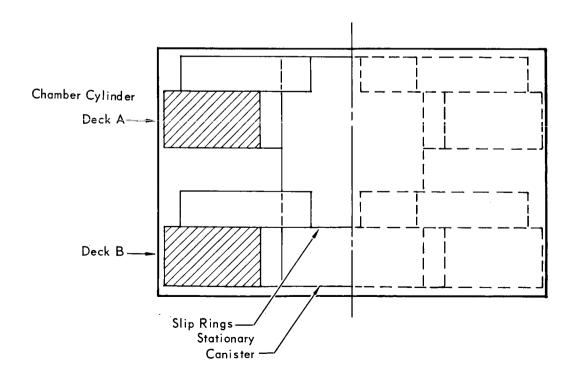### LIFE DETECTOR NO. 1 – GENERAL METABOLISM
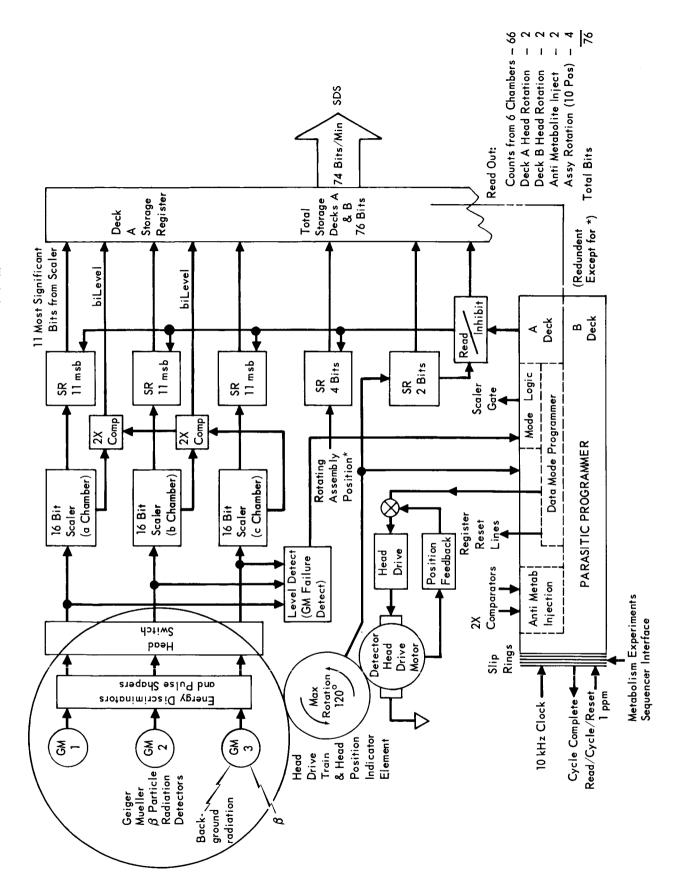### LIFE DETECTOR NO. 2 – PHOTOSYNTHESIS

Test Chamber
Cylinder Cluster

Sample Loading
and Delivery Initiator
Head Assembly

Rotating
Assembly

Rotary β
Detector
Head

Chamber Cylinder

Deck A

Deck B

Slip Rings
Stationary
Canister

ROTATING ASSEMBLY FUNCTIONAL FLOW DIAGRAM

Read Out:

Counts from 6 Chambers	– 66
Deck A Head Rotation	– 2
Deck B Head Rotation	– 2
Anti Metabolite Inject	– 2
Assy Rotation (10 Pos)	– 4
Total Bits	$\overline{76}$

(Redundent Except for *)

STATIONARY CANNISTER FUNCTIONAL FLOW DIAGRAM

Figure 14.3.9-6

14.3-88

TYPICAL IN SITU PROJECTABLE MODULE

Hard Line

Flexible Bellows

Electronic Module

Flexible Bellows

Bottom View

3"

1.2 Dia

Leg Release Squib

Metabolite/Antimetabolite Ampuls

Ampul Breaker

Ampul Breaker Squib

Flexible Bellows

Legs

Housing

Electronic Module

Orientating Pin

Geiger Detector

Primary Getter

Flexible Bellows

Secondary Getter Baffle

Secondary Getter Actuator

Secondary Getter Squib

Figure 14.3.9–7

14.3-39

in that liquid. Preferential scattering for transluscent organisms of about one micron size, in an aqueous culture, appears within a cone of 20 degrees from the direction of the illuminating light (see culture cell configuration in Figure 14.3.9-9). The conical interior of the culture cell is polished for good reflectivity. The complete assembly, Figure 14.3.9-8, consists of the optics housing (for coaxial alignment of the optics train), the culture cells and an arrangement of lamps, lenses and photo detectors. A diagram of the optics train used for each of the five cells appears in Figure 14.3.9-9.

The pH Component of Life Detector #3 - The purpose of the pH system is to monitor acidity changes in the bacterial cultures, thereby providing correlative information to turbidity data. A range of from 4 to 9 pH units with a total drift of less than 0.1 pH unit is desirable.

14.3.9-2 Design Requirements and Constraints - The major constraints that influence the design of these detectors are: (also see Part B, Paragraph 5.9.3.6)

    a. Maximum time for post landing operation of 27 hours.

    b. Sample obtained from an area which has been distrubed by the retro rocket plume.

    c. No true selectability of site sampled within the working area of the soil sampler.

    d. Time that is required to acquire,process and deliver sample.

    e. Landing time and site uncertainty.

    f. Central programming (SDS memory) that can be updated by command control.

    g. Each instrument is basic and not tied to any particular assay.

    h. Each instrument make available to the potential experimentalist multiple methods of experimental observation.

    i. An instrument array serving low resolution broadly non-selective detection objectives.

    j. Detectability is independent of a suitably prepared substrate in at least one instance.

    k. Continuity in detection objectives.

    l. Exclusive use of detection schemes that have been tested in the laboratory and in context with an engineering model of the flight instrument.

14.3.9.3 Physical Characteristics

Life Detectors #1 and #2 - Because of commonalities, life detectors #1 and #2 are contained in a single integrated cylindrical package of about one (1) cubic foot volume (15" in diameter and 9-3/4" in height) as shown in Figure 14.3.9-4. Sixty (60)

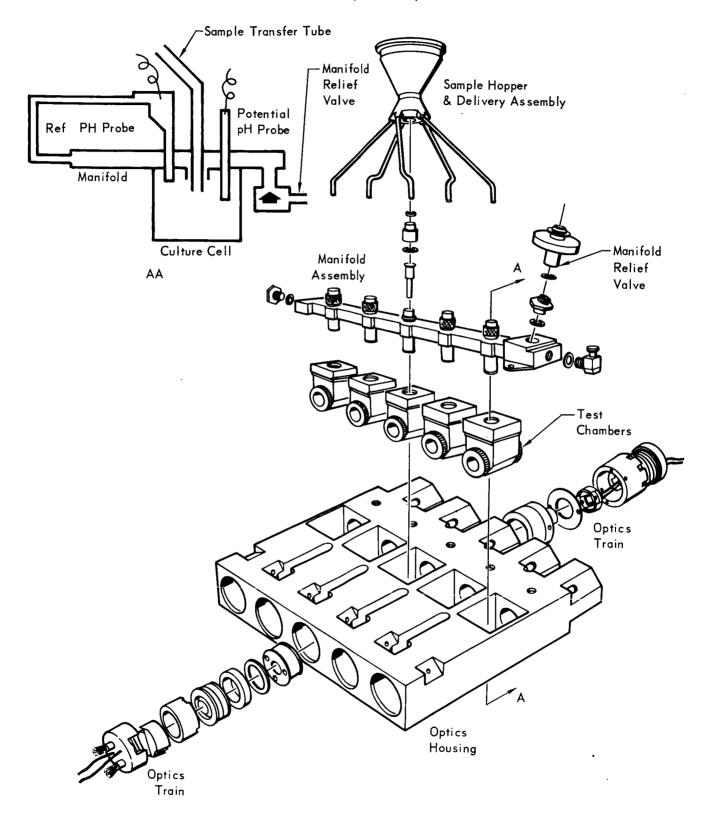## MAJOR FUNCTIONAL HARDWARE ELEMENTS OF
DETECTOR NO. 3 (GROWTH)

Figure 14.3.9-8

14.3-91

DETECTOR NO. 3 (GROWTH)
(FUNCTIONAL FLOW DIAGRAM)

Figure 14.3.9-9

14.3-92

culture chamber assemblies are circularly arranged in two like decks, one above the other. A rotating assembly carrying service elements for the chamber cylinder decks operates on a center with the stationary canisters and just above it. Service elements carried by the rotating assembly include the six (6) β detectors, the soil sample distribution equipment, and the initiator mechanism for sample, nutrient, and reagent dispensing. Eight of the detector #1 chambers are housed in 4 in situ deployable modules, each about 3 1/2 cubic inches and 100 grams. The physical appearance of these units is shown in Figure 14.3.9-7. The modules are stowed and deployed by mechanisms of 10 1/2 cubic inches each.
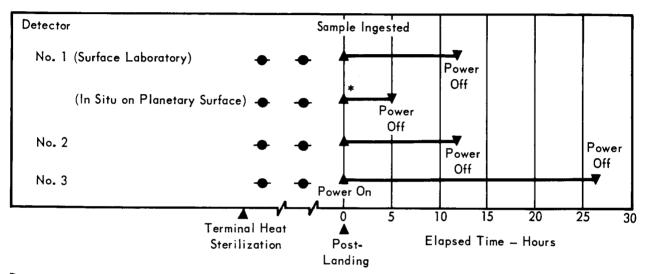
Life Detector #3 - Life detector #3 package consists of a rectangular volume housing detector components whose appearance is shown in Figure 14.3.9-8. The manifold assembly shown provides attachment points for the hopper-water/sample transfer tubes from above and for the culture cells from beneath. The manifold provides common venting to each culture cell at a point much higher than the maximum culture liquid height. A silicon rubber diaphragm pressure release valve fixes the maximum system pressure. The tap (extreme right of the manifold in Figure 14.3.9-8) pressurizes the space above the electrolyte in the reference pH probe to the same pressure as that above the culture liquid. The transparent windows, for optical determination of turbidity, are high quality fused quartz polished to minimize surface scratches. The windows are sealed by circumferential quadrings deformed by pressure loading on the screw-on sleeves acting through spacer rings.

14.3.9.4 Operation Description - Normal operation of the Laboratory based Life Detector starts after the required amount of sample has been delivered by the Surface Laboratory sampling system. For the in situ component of detector #1 operation begins with the deployment of the in situ modules. Since this deployment is contingent upon the availability of 5 consecutive hours of daylight it may or may not coincide with the start of operation of the laboratory based portion of detector #1. Both the in situ deployment function of detector #1 and the Sample processing, delivery and chamber preparation functions of detectors #1, #2, and #3 are similar with respect to the mechanism and effects of initiation. They are both initiated, independent of the SDS Memory, on a contingency basis (5 hrs. at daylight or sample delivery complete) and only provided they have been previously armed by the post landing output of the SL sequencer. The consequence of both functions are identically the irreversible utilization of the detector's expendable components such as nutrient media, anti-metabolities, gas collection capacity, etc. Such use of expendables is neither required not convenient prior to landing for pre-flight or in-flight monitoring

operations. Aside from one shot type operation, such as these, the detectors operate on the basis of repeating cycles (one minute science cycles and 10 minute engineering function cycles) each independently initiated by the SDS memory. Preflight or in-flight monitoring thus becomes a simple matter of adding extra pulse counts to the SDS Memory (one block for each Flight monitoring operation required), prior to initiating detector operation. See Figure 14.3.9-10 for the mission sequence of events.

The metabolism experiments sequencer, after receiving power, a post-landing arming signal and a report that sample ingestion has been completed, directs the parasitic programmer to distribute sample aliquots to each chamber. During this time, the sequencer also initiates appropriate engineering functions located about the stationary parts of package. After the sample delivery portion of the sequence has been completed (control aliquots sterilized and incubation begun), the sequencer returns a cycle complete signal to the SDS. This begins the inflow of READ/CYCLE/ RESET command pulses from the SDS via the detector sequencer; one/minute to the in situ programmer section and to the parasitic programmer, and one/10 minute to the engineering data programmer section. As each READ/CYCLE/RESET command companion line sees a cycle complete pulse the SDS memory block counts down one and initiates another READ/CYCLE/RESET pulse. The total number of pulses delivered times their interval determines the experiment duration. As an example of the function of this pulse, and at the same time that of the rotating assembly systems, reference is made to Figure 14.3.9-5. The detector head assembly, at each indexed portion of the rotating assembly, will service one, two or three test chambers each minute, depending on the number of Geiger tubes detected failed through a cycle of 10 indexed positions (one frame). For this reason science data points will be separated (for failure mode operation of more than one frame) as follows: with two failures – by 30 minutes, with one failure – by 20 minutes, and for normal operation with no failures – by 10 minutes. Since 20 to 30 minute intervals between data points would probably be the resolution of choice in the design of this experiment as repairable, serious compromise does not result from an inappropriately detected failure. Since remaining at one index position for more than one minute results in subsequent chamber counting with alternate Geiger tubes, such a failure also provides an opportunity to resolve offsets among test and replicate cultures. Position data is always included in the 76 bit word to the SDS, and therefore the mode of operation and the identity of the failed tube(s) is known. For each operational check required (prelaunch and cruise) the SDS memory sequences an appropriate block of READ/CYCLE/RESET pulses

14.3-94

MISSION SEQUENCE FOR LIFE DETECTORS

Detector   Sample Ingested

No. 1 (Surface Laboratory)   ●   ● ▲ ─────────────▼
                                                          Power
                                                          Off

    (In Situ on Planetary Surface) ● ● ▲ ──────▼*
                                                  Power
                                                  Off

No. 2   ● ● ▲ ──────────────────▼
                                                              Power   Power
                                                              Off   Off

No. 3   ● ● ▲ ─────────────────────────────────────▼
                                       Power On

         ▲   0   5   10   15   20   25   30
    Terminal Heat   ▲
    Sterilization   Post-   Elapsed Time — Hours
                                     Landing

─ Data return.

● Flight monitoring as programmed.

* Initiate as shown if SL sequencer start command occurs
  five hours prior to sunset, otherwise initiate at sunrise
  on the following day.

into the package (i.e., 20 one minute pulses for the rotating assembly parasitic programmer, two 10 minute pulses for the engineering programmer and four one-minute pulses for the in situ programmer).

In-Situ Modules - Four in situ modules are deployed at the first opportunity for 5 consecutive hours of daylight. The modules are projectable to points some 100 or more feet from the lander (one in each of the four lander quadrants). The soil that comes under test is, therefore, a section of planetary surface undisturbed by the lander retro rockets. Each module carries two chambers, one for test and one for control. The single nutrient that is carried is transferred by wick onto approximately a 1 cm^2 covered area of soil. The soil is thus wetted to some unknown depth. How the soil is wetted, however, also an uncertainty, stands to be a more significant variable. As suggested by terrestrial experience, the bias, if any, resulting from such wetting will be biologically favorable. That is, experience suggests that most soils act to a greater or lesser extent as a chromatographic bed, of sorts, in effecting composition and concentration gradients in an applied media (thereby increasing the opportunities of organisms for finding a favorable formulation). Opportunities for optimum wetting are restricted to certain daylight hours. After the test response has reached 2 times that of the control (background) the module initiates injection of an antimetabolite onto the covered sample.

Detector #3 - The normal and pre-flight or in-flight operations of detector #3 parallels that of detectors #1 and #2 with regard to their use of expendables. The tungsten lamp, burning at approximately 2,100°K, provides illumination for both the lamp monitor photocell and the condenser lens system. The lamp photocell automatically maintains the lamp intensity at a fixed value determined by the input network of the regulator amplifier. The condenser lenses focus an image of the lamp filament on the aperture plate which contains a 0.011 in. diameter hole. The illuminated aperture serves as the source for the collimator which beams parallel light rays through the transparent and windows of the cell. The imaging lens system focuses undeviated light passing through the culture on the image occulting disc. The disc blocks the non-scattered light from the signal photocell. Light ray deviations within the culture cell, due to soil particles and microorganisms, miss the occulting disc and are converted to an electrical signal in the photocell. The photocell electrical signal is then conditioned by the signal amplifier and made available as a voltage output.

14.3.9.5 Performance Characteristics - Figure 14.3.9-11 tabulates principal life detector performance characteristics.

CHARACTERISTIC	DETECTOR 1	DETECTOR 2	DETECTOR 3
Purpose	The detection of any of a wide variety of Earth type microorganisms	The detection of strict and facultative photo-synthetic autrotrophs and to provide data pertinent to phyco-chemical properties of soil gas exchange	The detection at any micron size viables that increase in size or number with time
Type of Instrument	Radioisotopic metabo-lism detector	Radioisotopic photo-troph detector	Optical and chemical growth detector
Performance Accuracy of scientific data Sensitivity and response time*	1% Metabolism by 10^4 micro-organisms for 1 hour**	1% Function of light or dark fixation period** (for a 1-hour period, about 10^2 phototrophs and 10^3 viables respectively)	1% 10^2 Viables in 10 to 14 hours****
Physical Character-istics (Detectors 1 and 2 combined) Weight Volume	25 Pounds (metabolism package at 22 pounds + 4 in situ modules at 3 pounds total) 1762 cu in (metabolism package at 1 cu ft + 4 in situ modules at 42 cu in total)		5 pounds 256 cu in.
Interface Character-istics (Detectors 1 and 2 combined) Power Data	9 Watts Scientific: 63,720 bits total (76 bpm for 12 hours & 30 bpm for 5 hours) Engineering: 3,900 bits total (55 bits per 10 min. for 12 hours)		1.5 Watts 2-0 to 5 volt analog lines 1-0 to 5 volt analog line Analog to digital conversion requires 38,880 bits (1,440 bits/hr for 27 hrs)

*Sensitivity is influenced by many factors not the least of which is the unknown viable endity (s) itself. For any given situation the rate and degree of respiration (metabolism and photo synthesis) may be affected by such factors as strain(s) characteristics, composition of growth medium, age and number of cells in an in-oculum, origin of inoculum, ages of culture when harvested for study, number and kinds of processes in ob-taining inoculum, composition of respiration system, amount of light, of other gases present, etc. Therefore, sensitivities given in this table are applicable only to the specified organisms**, *** as detected by the subject detector whose general sensitivity is itself a function of the specific activity of the appropriate radioisotope (that part of the nutrient constituent actually utilized by the unknown viable.)

**Given: A nutrient media, one of which constituent species (one utilized exclusively by the subject micro-organism) having a radioisotopic label whose specific activity is 3.6 millicurie/milli mole, which media, collectively, allows for the utilization by the microorganism of that constituent at a rate sufficient for them to expire the oxidation product $C^{14}O_2$ (or H_2S^{35} depending on the nature of the label) at the rate of 3×10^{-12} millimoles $C^{14}O_2$/cell-hour (the typical figure for the metabolism of glucose by E. coli); 10^4 such microorganism may be detected by this instrument within the first hour of experimentation, providing that the later results from the control tests (also performed by this instrument while on the Martian surface) bear out that such evolution of radioactive gas(es) as previously detected was in fact of biological origin.

***Examples given are for chlorella saccharophiles and E. coli respectively.

****This example is based on actual test using the engineering model of this instrument. The criteria for dection was a change in turbidity of 1% full scale. Athough about 5×10^6 E. coli were involved in producing this amount of change, the original inoculum consisted of less than 10^2 cells.

Figure 14.3.9-11

14.3-97

o <u>Life Detectors #1 and #2</u> - In addition to the data outputs directly pertinent to the construction of the typical types of curves depicted in Figures 14.3.9-12 and 14.3.9-13, the following data are returned to Earth: data pertinent to the figures as a function of incubation temperature; pH of an aliquot of heat sterilized soil and pH of an aliquot of unsterilized soil with and without the addition of an amount of pure water; background β activity from the soil sample; the amount of degradation of labled test media; and data pertinent to the physical-chemical properties of gas exchange operative in the delivered soil sample. Parameters which influence the performance of life detectors #1 and #2 are:

a. The three normal operating temperature plateaus: nominally $2^{\circ}C$, $15^{\circ}C$ and $35^{\circ}C$ and specimen-sample gas exchange test thermal profile of ambient to $1000^{\circ}C$.

b. Nutrient Milieu Selected:

   o Substrates - type and specific activity

   o Salts - types and amounts

   o pH - Amount of hydrogen ion activity

   o Osmolarity - diffusion potential

c. Anti-metabolite selected-efficacy and selectivity of action site.

The sensitivity of the experimental method of observation is:

d. C^{14} beta decay sensitivity $\sim 6.66 \times 10^{7}$ counts per minute per millicurie C^{14} (250,000 cpm full scale)

e. Beta decay resolution $\simeq 64$ counts per minute

o <u>Life Detector #3</u> - The principal data from detector #3 is the turbidity of each of 5 cultures as a function of time (Figure 14.3.9-13). As a correlate to the turbidity data, and contingent on a sterilizable pH probe, the pH of each culture is measured as a function of time.

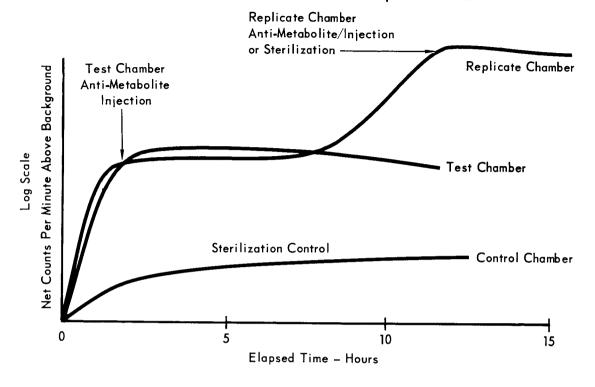Parameters which influence the performance of life detector #3 are:

a. Water to sample specimen ratio (osmolarity of mixture)

b. Nutrient milieu as applicable

c. Test temperature

The sensitivities of the experimental methods of observation are:

a. pH - range of 4 to 9 pH units with overall sensitivity and stability of 0.1 pH units

b. Turbidity - max sensitivity for 1μ size particles

TYPICAL LIFE DETECTOR DATA

LIFE DETECTOR NO. 1
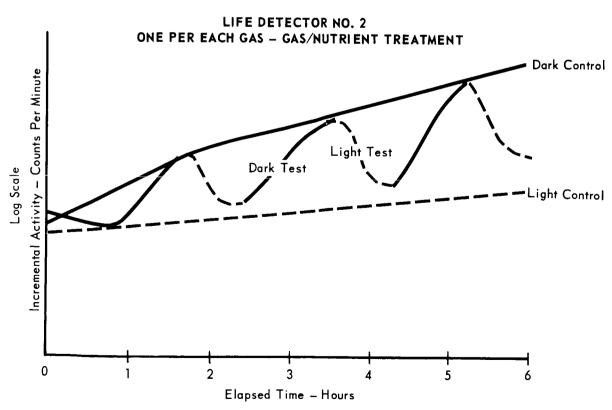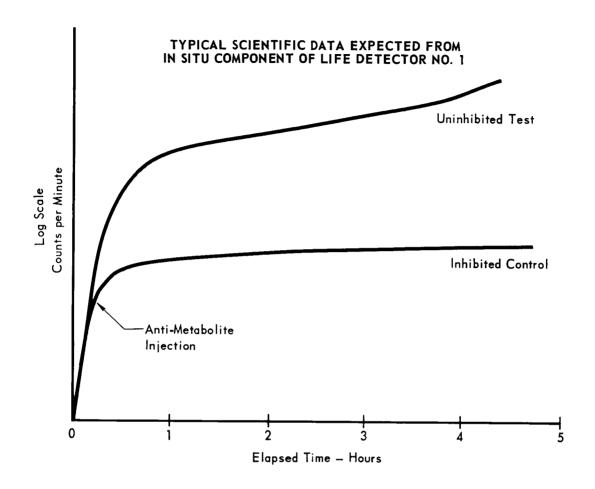## ONE PER EACH NUTRIENT/NUTRIENT pH TREATMENT

LIFE DETECTOR NO. 2
ONE PER EACH GAS – GAS/NUTRIENT TREATMENT

TYPICAL LIFE DETECTOR DATA

TYPICAL SCIENTIFIC DATA EXPECTED FROM IN SITU COMPONENT OF LIFE DETECTOR NO. 1

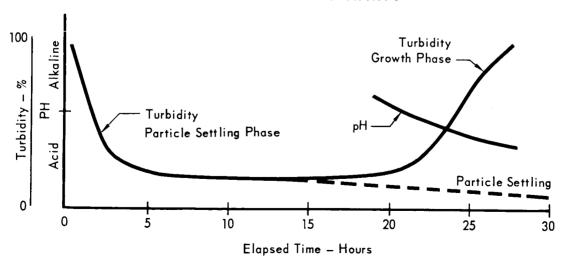## TYPICAL SCIENTIFIC DATA EXPECTED FROM LIFE DETECTOR NO. 3

Figure 14.39 – 13

14.3–100

Environmental Limits - The primary environmental stresses affecting the performances of the life detectors are high temperature and high radiation levels. Both of these stresses influence the integrity of the labeled substrates while temperature alone, so far as it is known, affects the integrity of the soil extract (where used). The environmental limits for detectors #1 and #2 are: during operation: $2^{o}C$ ($2^{o}C$ to $30^{o}C$ for _in situ_) and $<3 \times 10^{6}$ rads; during non-operation: $< 130^{o}C$ and $< 3 \times 10^{6}$ rads. The environmental limits for detector #3 are: during operation: $2^{o}C$ and 10^{6} neutrons/cm^{2} - hr and 10^{3} roentgen/hr gammas; during non-operation: $150^{o}C$ and 10^{13} (1 mev) neutrons/cm^{2} and 10^{7} roentgen of gammas. All detectors function in a 1.02 to 1×10^{-3} bar pressure ambient.
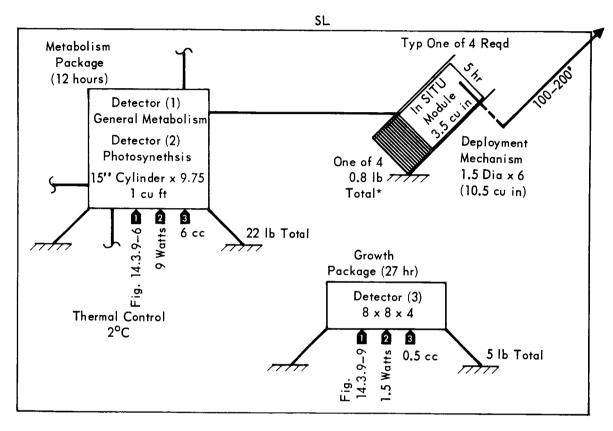
14.3.9.6 **Interface Definition** - The detector packages are shown in relation to the surface laboratory and its interfacing systems in Figure 14.3.9-14. General design requirements are also shown. A compilation of the detailed data and electrical interfaces and requirements is as follows:

Requirements

Specific Interface	Life Detectors #1 and #2	Life Detector #3
DATA OUTPUT		
Scientific Data	2 (76 bpm & 30 bpm)	2(0-5V analogs)
Engineering Data	1 (55 bits per 10 min)	1(0-5V analog)
Cycle Complete	3 (2-1/min 1-1/10 min)	3
SDS COMMANDS		
1/20 sec	0	3
1/min	2	0
1/10 min	2	0
SDS CLOCK (10 KH_{z})		
LABORATORY SEQUENCER	5 (1 post landing & 4 _in situ_ eject)	1
SAMPLE ACQUISITION AND PROCESSING (DELIVERY)	1 (6 cc)	1 (0.5 cc)
POWER SYSTEM	1 (28 $\pm$ 5 vdc)	1 (28 $\pm$ 5 vdc)
		1 (5 $\pm$ 0.005 vdc)

14.3.9.7 **Reliability and Safety Considerations** - High reliability in Detectors #1, #2 and #3 derives from the particular arrangements selected for their major components. CRITICAL elements such as the optics train in detector #3 would have to be constructed to minimize the possibility of failure. In the case of the optics train failure modes protected against are optical misalignments, abrasions of optical

LIFE DETECTOR INTERFACE DIAGRAM

Figure 14.3.9–14

surfaces, condensations on optical surfaces after heat sterilization, and lamp burn out following shock or vibration damage. Five independent culture systems and detection circuits allow for tradeoffs between experimental treatment and redundant or replicate tests.

14.3.9.8 <u>Test (Pre-Flight, In-Flight Monitoring and Checkout)</u> - The SDS selects and initiates all in-flight (and post terminal heat sterilization) monitoring of the three life detectors. In-flight checkout does not provide information on the status of expendables (efficacy of nutrient media and anti-metabolites, integrity of chemical gas collectors and their deployment mechanisms). Pre-flight monitoring utilizes a DUPLICATE SDS and power system interface and provides the same results as in-flight monitoring. Earlier tests can provide complete information on functional status by including a simulation of SL sequencer post landing signals. Because there is no provision for calibrating the pH probes against a standard buffer, and for evaluating the the effect of terminal heat sterilization on the optics train (condensate may form on protected optical surfaces), it would be desirable to consider the use of one of the 5 chambers for prelaunch and cruise checkout procedures (alternately a 6th chamber could be added).

14.3.9.9 <u>Development Requirement</u> - Further development effort is contemplated to flight qualify the selected detectors. Also, the following require considerable attention to bring about desirable and beneficial improvements:

<u>Detectors #1 and #2</u>

a. β detector conversion efficiency (present Geiger arrangement is about 6% efficient).

b. Chemical gas collectors (heat labile at pyrolysis temperatures, subject to deterioration with time, subject to shock and vibration damage).

c. Nutrient systems (some critical constituents are heat labile at sterilization temperatures, complete functional mechanisms not understood, need a broader spectrum of candidate substrates).

d. <u>In situ</u> module (surface seal questionable if deployed onto unfavorable terrain, thermal control requirements not suitably defined).
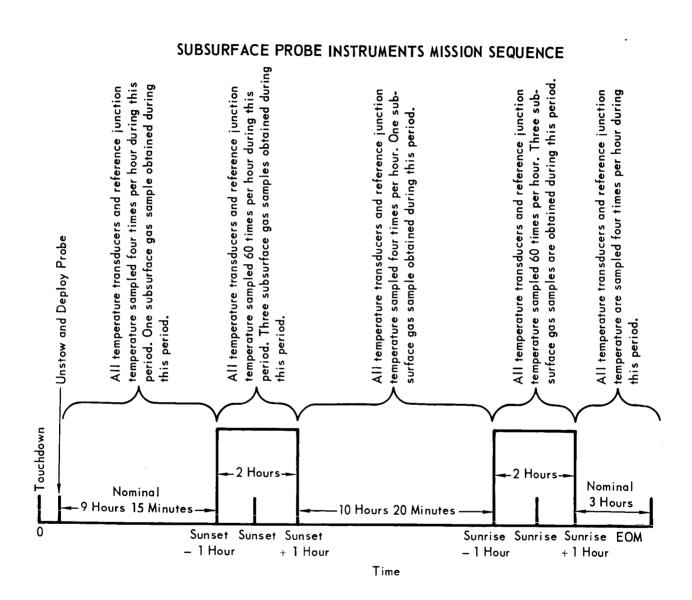
<u>Detector #3</u>

a. pH probe (currently available models are not completely reliable following heat sterilization).

b. Electro optics (better spectral match for expected range of microbe sizes, particle size limitations for settling time requirement and desired path length for the optical density requirements of a realizable instrument).

14.3.10 Subsurface Probe Sensors

14.3.10.1 <u>Equipment Identification and Usage</u> - The function of the subsurface probe instruments is to obtain periodic measurements of the subsurface temperature at several known depths. The temperature data will be correlated with local time-of-day to construct diurnal temperature profile plots as a function of depth beneath the surface. This data, together with atmospheric, surface data, and subsurface gas analysis will be time-correlated to provide an insight into the physical processes occurring on Mars. Nine thermocouples with their associated reference junction will perform this function. Figure 14.3.10-1 presents the mission sequence for these instruments.

14.3.10.2 <u>Design Requirements and Constraints</u> - The design of these sensors is influenced by the small volume available in the subsurface probe defined in Section 14.2.3 and by both physical and operational interface compatibility requirements. Interfaces between the probe structure and the thermocouples must be compatible. The reference junction must be compatible with the structural mounting provisions, thermal control temperature cycling, input voltage levels and regulation, and telemetry input signal characteristics. In addition, all wires must be deployable with the boom which is approximately 60 inches long.

14.3.10.3 <u>Physical Characteristics</u> - The thermocouples used to obtain the diurnal temperature variations as a function of depth are composed of materials which will yield an output of 35 to 40 mvdc at the maximum temperature difference between the reference junction and the sensed temperature. The reference junction dimensions are presently undetermined but the platinum resistance thermometer which is used to monitor its temperature is 1.50 x 1.25 x 0.4 inches for a volume of 0.75 cubic inches. The thermocouples are located in the probe as shown in Figure 14.3.10-2.

14.3.10.4 <u>Operation Description</u> - After the probe is deployed into the soil, the thermocouples will be read in accordance with a preprogrammed schedule to determine:

o Subsurface diurnal temperature variations as a function of depth beneath the surface

o Penetration depth of the probe in the soil.

The thermocouples are sampled at two different rates due to the varying rates of temperature change. Figure 14.3.10-3 shows a typical diurnal profile based on

SUBSURFACE PROBE INSTRUMENTS MISSION SEQUENCE

Unstow and Deploy Probe

All temperature transducers and reference junction temperature sampled four times per hour during this period. One subsurface gas sample obtained during this period.

All temperature transducers and reference junction temperature sampled 60 times per hour during this period. Three subsurface gas samples obtained during this period.

All temperature transducers and reference junction temperature sampled four times per hour. One subsurface gas sample obtained during this period.

All temperature transducers and reference junction temperature sampled 60 times per hour. Three subsurface gas samples are obtained during this period.

All temperature transducers and reference junction temperature are sampled four times per hour during this period.

Touchdown

Nominal
9 Hours 15 Minutes

2 Hours

10 Hours 20 Minutes

2 Hours

Nominal
3 Hours

0

Sunset
− 1 Hour

Sunset

Sunset
+ 1 Hour

Sunrise
− 1 Hour

Sunrise

Sunrise
+ 1 Hour

EOM

Time

Figure 14.3.10−1

14.3−105

SUBSURFACE PROBE THERMOCOUPLE
AND GAS SAMPLE PORT LOCATION

$\frac{1}{2}$ Scale

56° max

Surface

● = Thermocouple Location

▨ = Gas Sample Ports

0.6 In.

1.0 In.

8 cm

60" radius of curvature

15 cm

Typical
Section

0.50
0.80

22 cm

30 cm

0.4 In. Sq.

5 8 In.

TYPICAL MARTIAN SUBSURFACE DIURNAL TEMPERATURE PROFILE

Equations Used:

For T_S –

$$\alpha_S C = \rho \times C_p \frac{(T_{S_2} - T_{S_1})}{dt} + \sigma F_e F_A (T_{S_2}^4 - T_W^4) + \frac{k}{x}(T_{S_2} - T_i)$$

Where

$\alpha_S = 0.7$

$\rho = 139$ Lb./Ft.^{3}

$x = .0833$ Ft.

$C_p = .36$ BTU/Lb.°F

$dt = 1$ Hr.

$F_e = \epsilon_s \epsilon_w = .9 \times .95$

$C =$ Curve Below

$F_A = 1$

$T_W = 180$ °R

$k = 0.225$ BTU/Hr. Ft.^{2} °F/Ft.

$T_i = T_{S_2} - (T_{S_2} - T_{S_1}) f_1 \left(\frac{x}{\sqrt{adt}} \right)$

$a = \frac{k}{\rho C_p}$

$\sigma = .1714 \times 10^{-8}$ BTU/hr. ft.^{2} °R^4

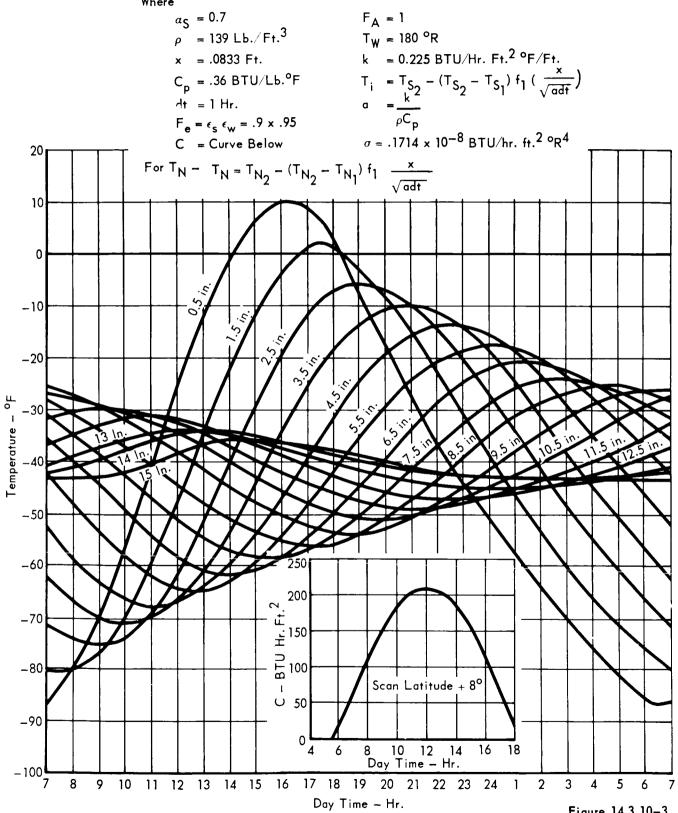For T_N – $T_N = T_{N_2} - (T_{N_2} - T_{N_1}) f_1 \frac{x}{\sqrt{adt}}$

Figure 14.3.10–3

14.3–107

calculations using a SiO_2 soil and a solar input corresponding to a +8°
latitude. These variations coupled with an even greater temperature rate of
change above the surface resulted in the selection of two sampling rates.
Periods of greatest activity occur around sunrise and sunset. Therefore, the
thermocouples will be sampled at a rate of one sample per minute for each
thermocouple during the intervals one hour before and one hour after sunrise and
sunset. During the rest of the mission the thermocouples will be sampled at
a rate of four samples per hour.

The reference junction is maintained at a stable temperature throughout the
entire surface mission and its temperature is measured every time the thermo-
couples are read out. Figure 14.3.10-4 presents a functionsl block diagram of
the temperature transducers.

14.3.10.5 <u>Performance Characteristics</u> – Selection of thermocouple materials which
would provide a 35 to 40 mvdc output for maximum reference junction/sensed
temperature difference will permit a $\pm$ 1% of full scale accuracy to be achieved.
Response times compatible with temperature changes pose no problems for the
selected sensors. The thermocouples will be fabricated from a single material
batch to ensure uniformity of thermocouple characteristics.

The reference junction temperature will be stable and always above the 330°K
upper range of the thermocouples. The reference junction temperature will also
be read to an accuracy of $\pm$ 1% of the full scale range of its temperature
transducer. Figure 14.3.10-5 presents the instruments' typical characteristics.

14.3.10.6 <u>Interface Definition</u> – The thermocouples are physically installed in
the probe structure with thermocouple wiring to the reference junction through
the probe and its boom. The reference junction interfaces with the Power,
Structural, Telemetry and the Thermal Control Subsystems. These interfaces
are tabulated in Figure 14.3.10-6. The probe temperature sensors interface
diagram is presented as Figure 14.3.10-7.

14.3.10.7 <u>Reliability and Safety Considerations</u> – Multichannel redundancy is
inherent by use of nine individual thermocouples. Data is retrieved in event
of a single or multiple thermocouple failure. Degradation of the single reference
junction will still allow experiment success provided that a junction temperature
is obtained from the platinum resistance thermometer.

There are no unique safety considerations relative to the subsurface probe
sensors.

SUBSURFACE PROBE TEMPERATURE TRANSDUCERS
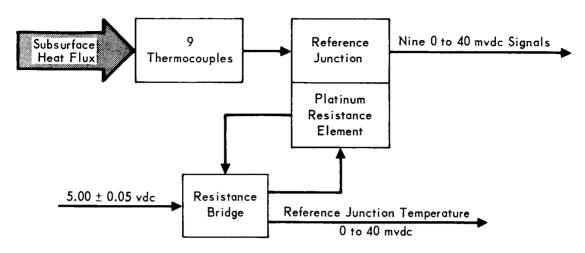## FUNCTIONAL SCHEMATIC DIAGRAM

Figure 14.3.10-4

SUBSURFACE PROBE INSTRUMENT CHARACTERISTICS

CHARACTERISTIC	THERMOCOUPLES	REFERENCE JUNCTION TEMPERATURE SENSOR
Range	150° to 330°K	Determined by reference junction operating temperatures and excursions
Accuracy	± 1% of full scale	± 1% of full scale
Output voltage	Approx. 0.25 mv/°K	0 to 40 mvdc
Materials	Determined by reference junction temperatures	Platinum resistance element
Number of measurements	332 over a nominal 27 hour mission. 60 sph for 4 hours plus 4 sph for 23 hours	332 over a nominal 27 hour mission – 60 sph for 4 hours plus 4 sph for 26 hours
Input voltage	NA	5.00 ± .05 vdc
Input power	NA	.01 watts
Location	Inside the subsurface probe	At known, stable temperature location above the 330°K upper range of thermocouples

Figure 14.3.10-5

14.3-109

REFERENCE JUNCTION INTERFACE REQUIREMENTS

INTERFACING SUBSYSTEM	INTERFACE
Power	5.00 ± 0.05 vdc for platinum resistance thermometer
Structural	Mounting for reference junction and its integral temperature sensor in the SL.
Telemetry	Ten 0 to 40 mvdc channels with sampling rates of 60 sph and 4 sph.
Thermal Control	Provide known temperature source for reference junction.

Figure 14.3.10–6

14.3–110

SUBSURFACE PROBE TEMPERATURE TRANSDUCERS
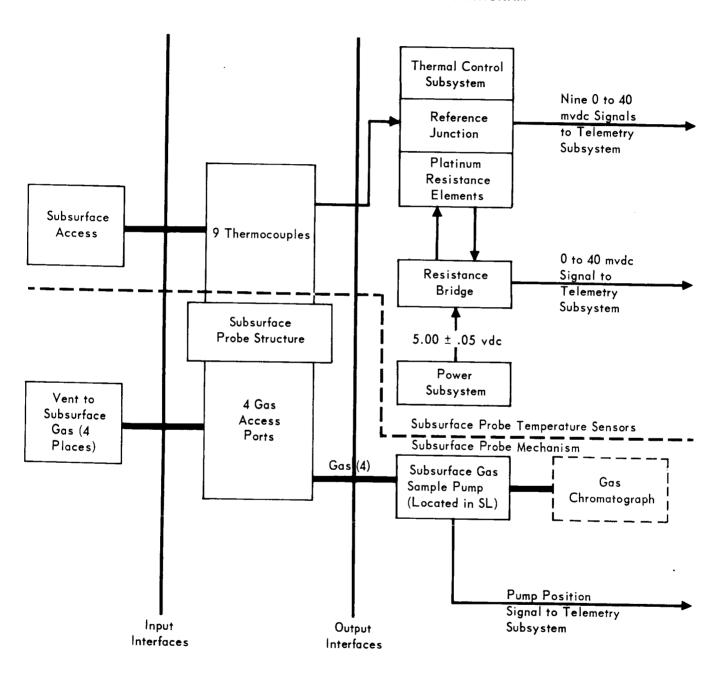## AND GAS ACCESS PORTS INTERFACE DIAGRAM

Figure 14.3.10--7

14.3-111

14.3.10.8 <u>Test Requirements</u> - Pre-flight checkout and in-flight monitoring requirements consists of:

  o Simple voltage and continuity checks, and

  o Temperature stability check of the reference junction

14.3.10.9 <u>Development Requirements</u> - All techniques and materials required to implement this instrument do exist; therefore, no advanced technology is required to meet the probe instrumentation requirements.